CS131–46
Mineral-Wool-Products, Industrial;
Test-Methods and Reporting

U. S. DEPARTMENT OF COMMERCE
HENRY A. WALLACE, Secretary

NATIONAL BUREAU OF STANDARDS
E. U. CONDON, Director

# INDUSTRIAL MINERAL WOOL PRODUCTS, ALL TYPES—TESTING AND REPORTING

## COMMERCIAL STANDARD CS131-46

Effective as a Basis for Testing and Reporting from March 15, 1946

A RECORDED VOLUNTARY STANDARD OF THE TRADE

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1946

For sale by the Superintendent of Documents, Government Printing Office,
Washington 25, D. C. - Price 10 cents

# PROMULGATION

of

## COMMERCIAL STANDARD CS131-46

for

## INDUSTRIAL MINERAL WOOL PRODUCTS, ALL TYPES—TESTING AND REPORTING

---

On September 28, 1945, at the instance of the Industrial Mineral Wool Institute, a proposed commercial standard for Industrial Mineral Wool Products, All Types—Testing and Reporting, was circulated to leading user organizations, Government agencies, distributors, and manufacturers for comment. Following numerous adjustments in the light of that comment, the recommended commercial standard was circulated on December 28, 1945 to the entire trade for written acceptance. Those concerned have since accepted and approved the standard shown herein for promulgation by the United States Department of Commerce, through the National Bureau of Standards.

The standard is effective as a basis for testing and reporting from March 15, 1946.

Promulgation recommended.

F. W. Reynolds,
*Acting Chief, Division of Trade Standards.*

Promulgated.

E. U. Condon,
*Director, National Bureau of Standards.*

Promulgation approved.

Henry A. Wallace,
*Secretary of Commerce.*

## CONTENTS

# INDUSTRIAL MINERAL WOOL PRODUCTS, ALL TYPES—TESTING AND REPORTING

## COMMERCIAL STANDARD CS131–46

---

### PURPOSE

1. The purposes of this standard are:
   (a) To serve the best interests of producers, distributors, and users by establishing standard tests for each type of industrial mineral wool product made of rock, slag, or glass, thereby eliminating confusion resulting from a diversity of test procedures.
   (b) To establish uniform testing and reporting for specific properties, the results of which can be compared and reproduced at any laboratory.
   (c) To provide an impartial source of information for the use of engineering societies and governmental and civilian testing laboratories concerned with the formulation of specifications on mineral wool products.
   (d) To reduce laboratory expense by establishing uniform procedures that require standard equipment to measure a particular property.

### SCOPE

2. This standard provides uniform methods for testing and reporting the physical and chemical properties of mineral wool products made of rock, slag, or glass and describes equipment required to produce standard results. Methods of test are included for adhesive strength, compressive strength, corrosion resistance, coverage, density, fire resistance, moisture adsorption, odor emission, shot content, temperature stability, and thermal conductivity. Combinations of test methods may be used to measure qualities familiar to the producer, distributor, and user that are not specifically designated by name.

### DEFINITIONS

3. A mineral wool product, a sample of which is submitted to a laboratory for test, shall be identified in the test report in a standard manner by the appropriate product name selected in accordance with the definition. Mineral wool and mineral wool products are defined as follows:

3a. *Mineral wool.*—Mineral wool insulation is rock, slag, or glass processed from a molten state into fibrous form.

(1) *Blanket.*—Mineral wool with or without binder added, reinforced on one or both sides with various types of confining media and suitably bound together.

(2) *Block*—Mineral wool with binder, compressed to desired density and dried, with or without surface coating, forming a rigid material normally furnished in sizes up to and including 12 in. by 36 in.

(3) *Board.*—Mineral wool with binder, compressed to desired density and dried, with or without surface coating, forming a rigid material normally furnished in sizes larger than 12 in. by 36 in.

(4) *Felt.*—Mineral wool with binder added, manufactured in semirigid form and furnished in flat sheets or rolls.

(5) *Granulated.*—Mineral wool mechanically processed into nodules.

(6) *Industrial batt.*—Mineral wool without binder added, manufactured in flat sheets or rolls.

(7) *Insulating cement.*—A dry mixture of mineral wool and other ingredients which when mixed with water to proper troweling consistency is suitable for application on heated equipment.

(8) *Loose.*—Mineral wool as originally processed and collected in a fluffy mass without regard to form or dimension.

(9) *Pipe insulation.*

(9) a. *Blanket-type.*—Mineral wool reinforced on one or both sides by various types of confining media and suitably bound together to form a nonrigid pipe insulation.

(9) b. *Molded-type.*—Mineral wool combined with other ingredients to form a rigid pipe insulation.

## SAMPLING

4. *Samples.*—Samples shall be selected in a manner to represent typical or standard manufacture of the product. They shall be systematically selected in a manner representative of the entire shipment.

5. *Number of samples.*—The number of samples shall be agreed upon between the client and the testing laboratory.

6. *Size of samples.*—The sample shall be of sufficient size to permit preparation for test as stipulated in each procedure.

## METHODS OF TESTING AND REPORTING

### I. ADHESIVE STRENGTH: INSULATING CEMENT

7. *Test specimen.*

7a. Approximately 10 lb of dry insulating cement or a sufficient quantity to provide three molded specimens.

8. *Apparatus.*

8a. A flat steel disk 6 in. in diameter, ⅜ in. thick, having a ¼-in. tapped hole in the center of one face into which may be screwed a hook with threaded shank. The flat surface of this plate shall have a mill scale intact, or it shall be prepared just prior to

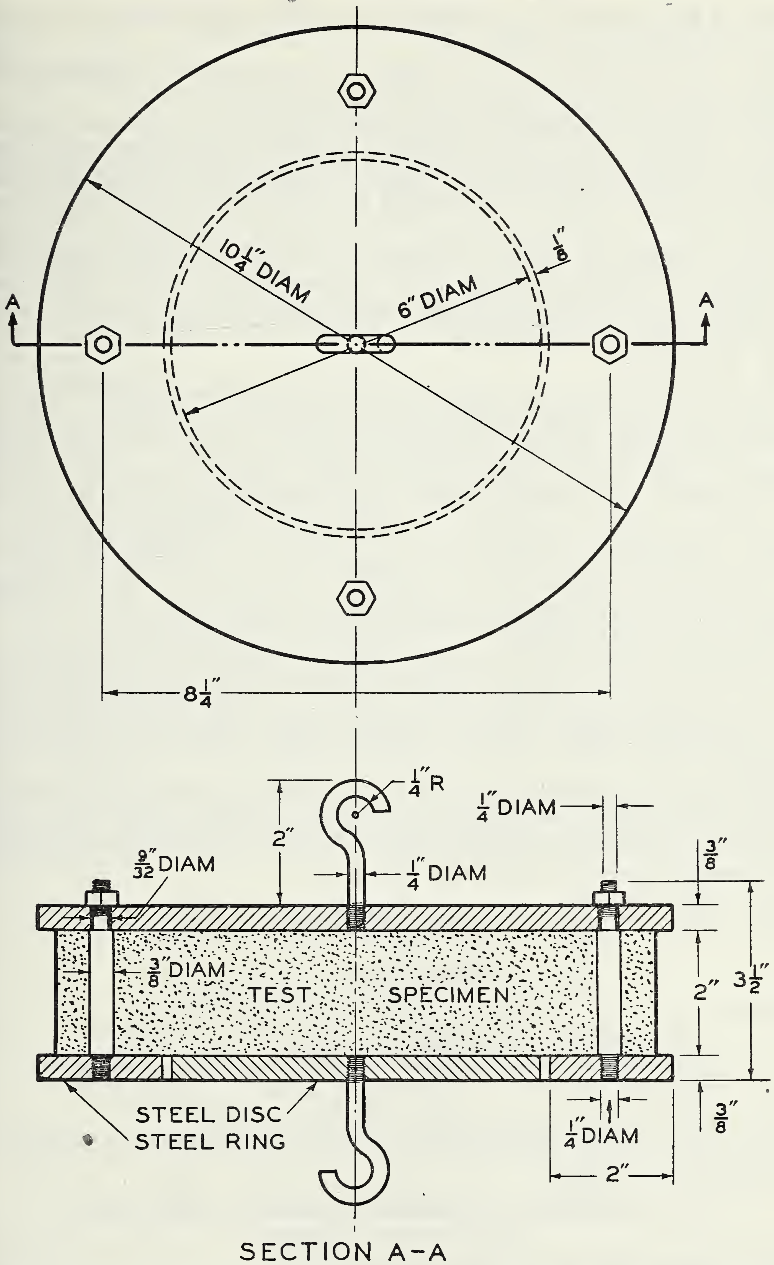



FIGURE 1.—*Assembly of heat insulating cement adhesion test apparatus.*

each usage by sanding it clean, etching in sulfuric acid of 1.3 specific gravity for 15 minutes, rinsing in clean water, and wiping it dry.

8b. A flat, annular steel ring 3/8 in. thick, inner diameter 6 1/4 in. and outer diameter of 10 1/4 in.

8c. A flat, rigid plate of metal or nonabsorbent material to support the annular ring with the disk inside it..

8d. Means for supporting or holding the annular ring while the disk is pulled from the cement, to which both ring and disk adhere. One form is shown in figure 1 and includes four studs set in the annular ring, to which may be attached an upper plate and hook.

8e. A standard testing machine or other suitable means of applying a measured load at a controlled rate. The total load capacity shall be not less than 300 lb, and the accuracy of measurement shall be within 5 lb.

9. *Procedure.*

9a. The annular ring shall be laid with the disk inside it on the flat, rigid plate so as to present a flat surface, with the tapped hole in the disk facing downward. Both ring and disk shall be covered with a 2-in. thick layer of the insulating cement mixed with water in accordance with the manufacturer's directions. A ring 2 3/8 in. high and 10 5/16 in. inside diameter may be used as a form outside the annular ring to assist in getting the proper thickness and shape, but this should be removed before drying. The cement supported on the disk, ring and plate shall then be dried to constant weight at 225° F in a vented oven.

After the cement drys, a hook shall be attached to the center of the disk, the supporting means for the ring put into position, and a load applied to pull the disk from the dried cement. The rate of load application shall be uniform and shall not exceed 100 lb/min.

The load required to pull the disk from the body of the cement shall be recorded, including the weight of the disk, hook, and any other apparatus, whose weight is part of the force required to separate the disk from the cement.

10. *Calculations.*

10a. The adhesive strength shall be determined as follows:

$$S=\frac{W}{28.27},$$

where

$S$ = adhesive strength in lb/sq in.

$W$ = load in lb required to separate disk and cement

28.27 = area of the 6-in. disk in sq in.

11. *Report.*

11a. The adhesive strength reported shall be the average of three determinations.

## II. COMPRESSIVE STRENGTH: BLOCK, BOARD, AND INSULATING CEMENT

12. *Test specimens.*

12a. At least four specimens of block or insulating cement shall be tested. Insulating cement specimens shall be cut from the molded and dried material. Preferably, they shall be 6 in., but in no case less than 5 in. square, and shall be of the same thickness, preferably 1 1/2 in. In the case of blocks 3 in. in width, two pieces, each 6 in. in length, shall be cut from the same block and tested side by side simultaneously; the two pieces shall count as one test specimen.

12b. The specimens shall be cut from larger blocks or irregular shapes in such a manner as to preserve as many of the original surfaces as possible. Only one specimen shall be cut from a single block or shape. The bearing faces of the test specimens shall be approximately parallel planes. Where the original surfaces of the block are substantially plane and parallel, no special preparation of the surfaces will usually be necessary. In preparing specimens from pieces of irregular shape, any means, such as a band saw, may be used that will produce a specimen with approximately plane and parallel faces without weakening the structure of the specimen.

13. *Apparatus.*

13a. Any form of standard hydraulic or mechanical compression testing machine and suitable means for measuring deformation.

13b. A spherical bearing block having a plane bearing surface at least 6 in. square.

14. *Procedure.*

14a. The test specimens shall be dried to constant weight at 225° F.

14b. The specimens shall be tested immediately upon removal from the drying oven.

14c. The load shall be applied perpendicular to the square face of the test specimen.

14d. The sperical bearing block shall be used on top of the test specimen in a vertical testing machine. The plane bearing surface of the block assembly shall be in contact with the entire area of the top surface face of the test specimen. (See fig. 2.) The spherical seat of the bearing block shall be kept thoroughly lubricated to insure accurate adjustment.

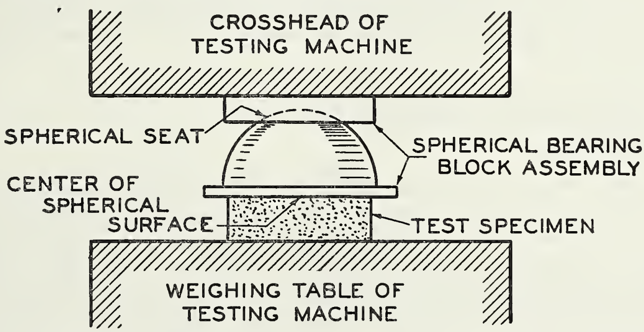



FIGURE 2.—*Spherical bearing block for compressive strength test of block and insulating cement.*

14e. The speed of the moving head of the testing machine shall be not more than 0.01 in./min. for each percent of specified deformation of the original thickness. For example, if 5-percent deformation is specified, the maximum speed of the moving head

694860—46—2

would be 0.05 in./min. Similarly, for 10-percent deformation of the original thickness, the maximum head speed would be 0.1 in./min.

14f. The specimen shall be compressed until definite fracture occurs, or until the specified maximum percentage deformation of the original thickness is reached. At least five (5) determination measurements shall be made at approximately equal percentage increments. For rigid materials, the maximum deformation required may be 5 percent of the original thickness; for resilient or compressible materials, the maximum specified deformation may be higher.

15. *Calculations.*—The compressive strength for any given percentage deformation shall be calculated as follows:

$$S=\frac{W}{A},$$

where

$S$ = compressive strength in lb/sq in.

$W$ = load in lb to produce specified deformation or fracture

$A$ = average of the gross areas of the top and bottom faces of the specimen in sq in.

16. *Report.*

16a. The report shall include a graph showing the average relationship of compressive strength vs. deformation for the specimens tested.

## III. CORROSION RESISTANCE: OTHER THAN INSULATING CEMENT

17. *Test specimen.*—Two specimens shall be used, each measusing 1 in. by 4 in. by approximately ½ in. thick.

18. *Apparatus.*

18a. Two polished-steel test plates 1 in. wide, 4 in. long and 0.020 in. thick. They shall be of clear finish, cold-rolled strip steel, American quality, quarter hard, temper No. 3, weighing 0.85 lb/sq ft.

18b. Tape or twine.

18c. Humidity test chamber.

19. *Procedure.*

19a. The steel test plates shall be rinsed with cp benzol until their surfaces are free from oil and grease and allowed to dry. One piece of cold-rolled steel shall be placed between the two insulation specimens and secured with tape or twine. The test specimen and uncovered plate shall be suspended vertically in an atmosphere having a relative humidity of 95 percent ± 3 percent, and a temperature of 120° ± 3° F, for 96 hours, and then be examined for corrosion.

20. *Report.*

20a. The report shall include a description of the degree and extent of any visible corrosion on the test plate, and a corresponding description of the condition of the blank test plate.

## IV. COVERAGE: INSULATING CEMENT

21. *Test specimen.*

21a. The sample shall be about 5 lb, or a sufficient quantity to nearly fill the mold, after mixing with water.

22. *Apparatus.*

22a. A flat, rigid mold having inside dimensions of 1 in. by 12 in. by 36 in., with one end and one face open, and a piece of wood or other suitable material 1 in. by 2 in. by 11⅞ in. in dimensions for squaring the end of the test specimen toward the open end of the mold. (See fig. 3.)

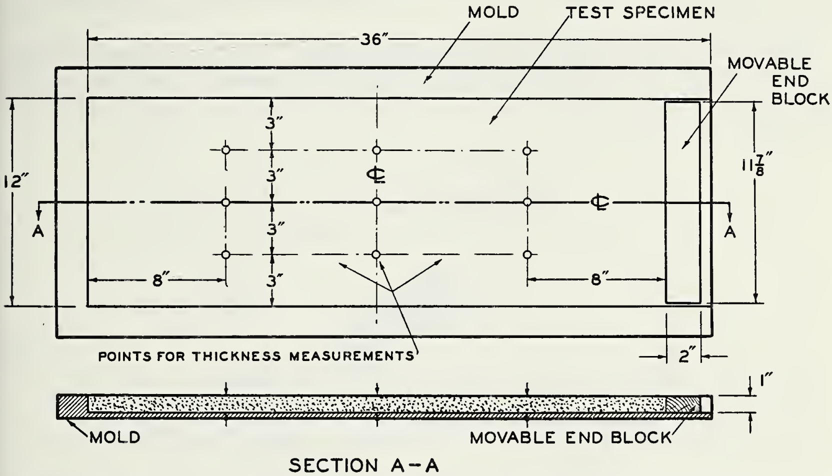



FIGURE 3.—*Mold for insulating cement test specimens and locations of points for thickness measurement.*

22b. Engine oil or sheets of waxed paper 12 in. by 36 in. for lining the mold.

22c. A 16-in. rectangular plasterer's trowel.

22d. Two steel rules 18 in. and 36 in. long, graduated in 1/64-in. intervals.

22e. A depth gage for measuring thickness of test specimens of the type shown in figure 4, except that the flat disk shall be about ½ in. in diameter.

22f. A vented drying oven having a volume at least 50 times that of the specimens.

22g. Scales accurate within ¼ ounce.

23. *Procedure.*

23a. The sample of dry insulating cement shall be accurately weighed and mixed with clean, fresh water, in accordance with the manufacturer's directions.

23b. The inside of the mold shall be oiled or lined with waxed paper to prevent the cement from sticking and to permit removal of the specimen after drying. The mixed cement shall then be placed in the mold.

23c. The cement shall be troweled in one layer and in two directions without unnecessary compacting, until the surface is smooth and flush with the top edges of the mold. The cement at the open end of the mold shall be squared off and the movable endpiece pressed against it so as to form a rectangular specimen. The troweling shall be finished in such a manner that the width and thickness of the wet cement are equal to the width and depth of the mold.

23d. The length of the wet specimen shall be measured from the inside of the fixed end of the mold to the inside edge of the movable endpiece. Measurements shall be made at two locations approximately 2 in. from each side of the mold. While making these measurements, the edge of the steel rule shall be allowed to make an indentation in the wet cement to mark the point of measurement.

23e. The point of the depth gage shall be carefully pushed vertically through the wet cement until it comes in contact with the bottom of the mold at nine points spaced over the flat surface, as shown in figure 3.

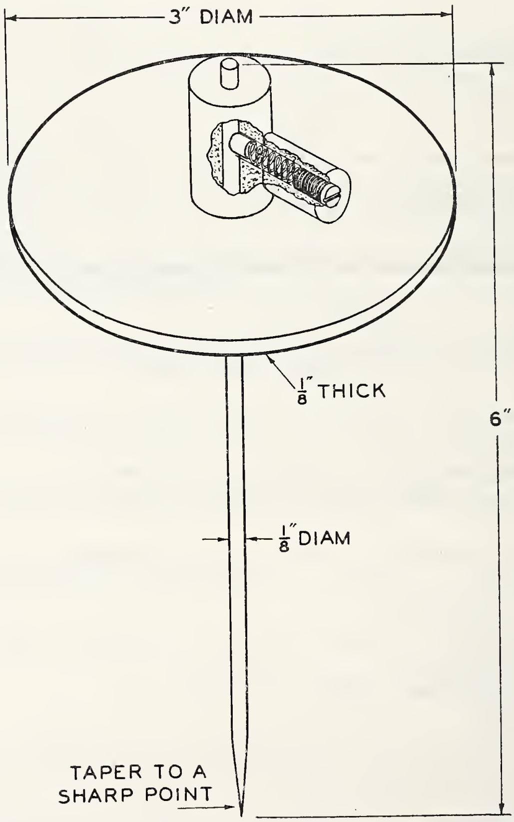



FIGURE 4.—*Depth gage for thickness measurements of industrial batt, blanket, felt and blanket-type pipe insulation. For Industrial Cement Test the Flat Disk shall be ½ inch in diameter instead of 3 inches.*

23f. Immediately after the measurements have been made, the mold and contents shall be dried in the oven at 225°F until the weight is constant.

23g. After drying the specimen, it shall be measured for length, width, and thickness. The length shall be measured at the same two points as before, the width at two points located 6 in. from each end and the thickness at the points where holes were made by the depth gage in the wet cement. In order to prevent false thickness measurements of the dry specimen due to warpage, the specimen shall be removed from the mold and a flexible steel rule placed in contact with the bottom at the point where thickness is to be measured. The point of the depth gage shall be inserted from the top until it touches the steel rule. The dried specimen shall be weighed.

24. *Calculations.*

24a. The wet and dry coverage, the volume change upon drying, and the dry density shall be calculated as follows:

$$C_w = \frac{dbl}{144W} \times 100$$

$$C_d = \frac{d_1 b_1 l_1}{144W} \times 100$$

$$V = \frac{(dbl) - (d_1 b_1 l_1)}{dbl} \times 100$$

$$D = \frac{W_d \times 1728}{d_1 b_1 l_1},$$

where

$C_w$ = wet coverage in square feet 1 in. thick per 100 lb of dry cement
$C_d$ = dry coverage in square feet, 1 in. thick per 100 lb of dry cement
$V$ = volume change upon drying in percent
$d$ = thickness of molded wet cement (assumed to be depth of the mold in in.)
$b$ = width of molded wet cement (assumed to be width of the mold in in.)
$l$ = average length of molded wet cement in in.
$W$ = weight of sample of dry cement in lb
$W_d$ = weight of dried specimen in lb
$d_1$ = average thickness of dried specimen in in.
$b_1$ = average width of dried specimen in in.
$l_1$ = average length of dried specimen in in.
$D$ = dry density in lb/cu ft.

25. *Report.*

25a. The report shall include the following:

1. Wet coverage.
2. Dry coverage.
3. Volume change upon drying.
4. Dry density.

## V. DENSITY AND THICKNESS

### (a) INDUSTRIAL BATT, BLANKET, FELT, AND BLANKET-TYPE INSULATION

26. *Test specimens.*

26a. The size of the specimen shall not be limited, but shall be of commercial size whenever practicable.

27. *Apparatus.*

27a. Depth gage (See fig. 4.)

27b. Steel rule graduated in 1/32-in. intervals.

27c. Scales accurate to within 1/4 oz.

28. *Procedure.*

28a. Dimensional measurements. — (1) Thickness: The test specimen shall be ruled off into 10 approximately square and equal areas and a thickness measurement taken at the center of each area. In making the thickness measurements, the test specimen shall be placed on a hard, flat surface, and the penetrating pin of the depth gage (see fig. 4) shall be forced downward through the specimen, perpendicular to the flat surface. If necessary to prevent compression of the specimen by the depth-gage pin, the specimen shall first be pierced. When the point of the pin touches the flat surface, the sliding disk shall be lowered to the point of contact with the top surface of the specimen. The gage shall be withdrawn and the distance from the point of the pin to the sliding disk measured to the nearest 1/32 in. In the case of metal-mesh blanket insulation, the reinforcing material, regardless of its nature, shall not be removed when making thickness measurements. However, in the case of rib lath reinforcement, the thickness measurements shall be made between ribs or, where this is not practical, the height of the ribs shall be deducted from the total thickness as measured with the depth gage. (2) Length and width: The length and width of the specimen shall be measured to the nearest 1/32 in. In the case of products having surface reinforcements such as metal-mesh blanket insulation, etc., the width and length shall be measured on the insulation rather than on the facing material.

28b. Weight measurements.—The test specimen used for the thickness measurements shall be weighed to the nearest 1/4 oz. In the case of metal-mesh blanket insulation, the weight of the reinforcing materials shall be deducted from the total weight of the specimen in computing density.

29. *Calculations.*

29a. Thickness.—The average of the 10 thickness measurements made in accordance with paragraph 28a (1) shall be taken as the "thickness as received" of the test specimen.

29b. Density.—The "density, as received" and the "density, at specified thickness" shall be calculated as follows:

$$\text{“Density, as received'' (lb/cu ft)} = \frac{W \times 1728}{l \times b \times d_1}.$$

$$\text{“Density, at specified thickness'' (lb/cu ft)} = \frac{W \times 1728}{l \times b \times d_2}$$

where

$W$ = weight of test specimen in lb
$l$ = length of specimen in in.
$b$ = width of specimen in in.
$d_1$ = "thickness, as received"
$d_2$ = thickness specified on ordering or designating the material.

30. *Report.*—The report shall include the following:
30a. "Density, as received" expressed in lb/cu ft.
30b. "Density, at specified thickness" expressed in lb/cu ft.

### (b) BLOCK AND BOARD INSULATION

31. *Test specimen.*
31a. The size of the specimen shall not be limited but shall be of commercial size whenever practicable.
32. *Apparatus.*
32a. Steel rule graduated in 1/32-in. intervals.
32b. Scales accurate to within 1/4 oz.
33. *Procedure.*
33a. The specimen shall be measured at three locations for length, width, and thickness to the nearest 1/32 in. From the average of at least three measurements for each dimension, the volume shall be computed. The specimen shall be weighed to the nearest 1/4 oz.
34. *Calculations.*
34a. The density expressed in lb/cu ft shall be calculated from the weight and computed volume.
35. *Report.*
35a. The density shall be reported.

### (c) MOLDED-TYPE PIPE INSULATION

36. *Test specimens.*
36a. The size of the specimen shall not be limited, but shall be of commercial size whenever practicable.
37. *Apparatus.*
37a. Steel rule graduated in 1/32-in. intervals.
37b. Scales accurate to within 1/4 oz.
38. *Procedure.*
38a. Any jacket on the specimen shall be removed and the inside diameter, outside diameter, and length measured to the nearest 1/32 in. with a steel rule, at least four measurements of each dimension being taken. Thickness shall be taken as the average outside diameter minus the average inside diameter, divided by two. The specimen shall be weighed to the nearest 1/4 oz.
39. *Calculations.*
39a. The density expressed in lb/cu ft shall be calculated from the weight and computed volume.
40. *Report.*
40a. The density shall be reported.

## VI. FIRE RESISTANCE: ALL MINERAL WOOL PRODUCTS

41. *Test specimen.*
41a. The size of the specimen shall be sufficient to cover an area approximately 36 in. sq at customarily installed thicknesses.
42. *Apparatus.*
42a. An incombustible backing support, 36 in. sq, for mounting the specimen. For loose or nonrigid materials, a 4 by 4-mesh standard hardware cloth shall be used to hold the specimen against the backing.

42b. A square frame having inside dimensions of 30 in. made of 2 in. by 2 in. by 1/8-in. angle iron, with legs to hold it horizontally 30 in. or more above the floor.

42c. A Bunsen-type gas-air burner with a 3/4-in. or 7/8-in. diameter outlet.

42d. A chromel-alumel No. 8 B & S gage thermocouple having the hot junction and adjacent wire bent into a circle 3 in. in diameter and mounted horizontally.

42e. A potentiometer or other means of reading temperatures with the thermocouple.

43. *Procedure.*

43a. For certain uses and types of application mineral wool products are covered with facing materials. Except in the case of metal facings, the facings shall be removed and tested separately.

43b. The specimen shall be mounted on the incombustible backing support either mechanically or by other means that will not permit it to become loose when heat is applied. Loose, or nonrigid, materials shall be supported by the metallic screen. Before a test, the specimen shall be dried to constant weight at a temperature of 225°F.

43c. After mounting the specimen, it shall be placed in a horizontal position on the flat surface of the angle-iron frame with the specimen facing downward. The gas-air burner shall be placed in position so that its flame will be directed to the center of the specimen face. The top of the burner shall be 28 3/4 in. below the face of the specimen. The coil of the thermocouple shall be mounted 1 in. below the face of the specimen with the hot junction opposite its center and with the wires bare for at least 2 in. from the junction.

43d. The test shall be conducted in a room free from drafts or appreciable air currents and having a temperature of between 60° and 85°F.

43e. Flame from the gas-air burner shall be applied during a test period of 40 min and shall be regulated to give temperatures at the thermocouple according to the "Columbia" time-temperature curve shown in figure 5. Temperature readings shall be taken at intervals not exceeding 2 min throughout the test. The area under the completed curve plotted from the readings shall be within 5 percent of that of the reference curve. The flame shall touch the specimen during the entire period, excepting only the first 5 min if required for temperature regulation. At no time should the flame cover an area of the specimen face greater than a 12-in.-diameter circle.

43f. The test specimen shall be left in place after removal of the flame, until it has cooled, to note any tendency toward smoldering.

43g. During the test, observations shall be made and notes kept on the following points in addition to the time-temperature record:

1. Whether or not flame issues from specimen at any time during or after the test.
2. In case of flaming, whether the flame is sustained or in short, intermittent flashes.
3. In case of flaming, whether or not it reaches the angle-iron frame at any time.

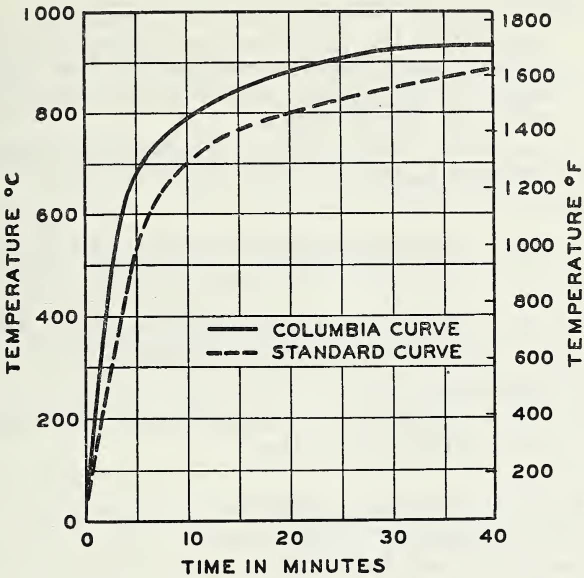



FIGURE 5.—*"Columbia" and "Standard" time temperature curves.*

4. Whether or not a flame continues for 2 min or longer after removal of test flame.
5. Whether or not a glow appears at the edge of the specimen at any time during or after the test, indicating progressive combustion within the specimen.
6. Whether or not the specimen remains in place or portions of burned, charred, or disintegrated material fall from it, except that portions having a total area less than 50 sq in. shall not be counted.
7. Whether or not self-sustained combustion ceases upon removal of test flame.
8. Extent of smoke and fumes emitted.

44. *Classification.*

44a. From the observations the specimen shall be rated in one of the following classifications:

1. *Incombustible.* The material has remained in place, no flame issued from it, no glow has appeared at its edge, and no smoldering afterward was evident.
2. *Fire-retardant.* The material has remained in place, no sustained flame has issued from it and any flame which occurs shall be limited to intermittent short flame from the area directly exposed to the test flame. No flame from the specimen has reached the angle frame at any point. No glow has appeared at its edge, all flaming has stopped within 2 min after removal of the test flame and no smoldering afterward was evident.

694860—46—3

3. *Slow-burning.* The material has remained in place, no flame from the specimen has reached the angle frame at any point during or after the flame application, and all flaming has ceased within 5 min after removal of the test flame.
4. *Combustible.* Material not falling in the above three classifications.

45. *Report.*

45a. The report shall include the time-temperature curve, the observations taken during the test, and the rating of the material.

## VII. MOISTURE ADSORPTION: ALL MINERAL WOOL PRODUCTS EXCEPT INSULATING CEMENT

46. *Test Specimen.*

46a. The specimen shall be of a size that can be conveniently tested in the humidity test chamber.

47. *Apparatus.*

47a. A drying oven or desiccator.

47b. Scales accurate to within ¼ oz.

47c. A humidity test chamber.

48. *Procedure.*

48a. The specimen shall be measured to determine volume, then dried to constant weight, and the weight recorded. It shall then be brought to a uniform temperature of not less than 120° F and transferred to the humidity chamber. The specimen shall be suspended vertically within the chamber, and shall be protected from condensate dripping from the chamber ceiling by a slanting false roof immediately above the specimen.

48b. The specimen shall remain in the humidity chamber for 96 hr at a temperature of 120° ± 3° F and at a relative humidity of 95 percent ± 3 percent, then removed, and immediately reweighed.

49. *Calculations.*

49a. The percentage moisture adsorption by weight and by volume is calculated as follows:

$$MA_w = \frac{\text{weight after test} - \text{weight (dried)}}{\text{weight (dried)}} \times 100$$

$$MA_v = \frac{MA_w \times \text{weight (dried) in grams}}{\text{volume in cu cm}} \quad \text{or}$$

$$= \frac{MA_w \times \text{weight (dried) in pounds}}{0.036 \times \text{volume in cu in.}}$$

where

$MA_w$ = moisture adsorption in percent by weight
$MA_v$ = moisture adsorption in percent by volume.

50. *Report.*

50a. The report shall include the percentage moisture adsorption by weight. It shall include the percentage moisture adsorption by volume only when specified.

## VIII. ODOR EMISSION: LOW-TEMPERATURE INSULATIONS

51. *Test Specimens.*

51a. Three specimens of insulation of given thickness shall be cut to a size approximately 6½ in. wide by 10 in. long.

52. *Apparatus.*

52a. Electric refrigerator.

52b. Six porcelain enameled refrigerator pans measuring approximately 6¾ in. wide by 10½ in. long by 3½ in. deep, with snug-fitting lids.

52c. Six 2-in.-sq pieces of window glass.

52d. Unsalted, sweet cream butter, less than 72 hr old, cut into pats 1 in. square by ¼ in. thick.

52e. All equipment shall be kept thoroughly clean and odor-free. Before each test, the pans, the glass squares, and the knife with which the butter is cut shall be sterilized. The refrigerator must be kept free from odor and in good operating condition at all times.

53. *Procedure.*

53a. The six pats of butter shall be placed on the six sterilized squares of glass. One piece of glass with butter thereon shall be placed on top of each of the three insulation specimens and placed in separate enameled pans. The other three pieces of butter shall be placed in separate enameled pans without insulation specimens to serve as blanks during the test. The lids shall be replaced and all pans put into an electric refrigerator. The refrigerator shall be operated at normal temperature (about 46° F) for 24 hr, at which time the pans are removed and odor and taste tests made.

53b. Odor.—Observation of odor emission shall be made by at least three observers. After removing the pans from the refrigerator, the lids of each pan shall be raised slightly at one end and allowed to drop. Any odor expelled should be noted and recorded, comparing in each case the odor from a pan containing an insulation specimen with that from a pan without insulation specimen.

53c. Taste.—Taste tests shall be made by at least three observers. Remove the butter pats from the six pans and cut small uniform pieces from the corners of each pat. The taste of the butter from each of the three insulation specimens shall be compared with the taste of a blank pat of butter.

54. *Report.*

54a. The report shall include all observations of the odor and taste tests, as follows:

1. No apparent difference.
2. Slight trace.
3. Strong or objectionable.

## IX. SHOT CONTENT: INDUSTRIAL BATT, BLANKET, FELT, GRANULATED, LOOSE, AND BLANKET-TYPE PIPE INSULATION

55. *Test specimen.*

55a. A specimen weighing 15 to 25 g shall be used. For fabricated materials, the specimen shall be cut from the sample with a knife or cork borer, taking care that no particles are lost.

56. *Apparatus.*

56a. A furnace capable of heating the specimen to at least 1,000° F, and of maintaining that temperature.

56b. A pan for holding the specimen during the heating.

56c. A balance accurate to 0.05 g.

56d. Three 8-in. diameter U. S. Standard Sieves (Nos. 10, 30, and 50), nested in order, with a top cover and bottom receiver.

56e. Three large-diameter rubber stoppers (No. 12 or 13).

57. *Procedure.*

57a. Weigh the specimen, using the pan to avoid any loss while handling, then heat in the furnace to 1,000° F or higher to remove or carbonize organic matter. The temperature must not be high enough to melt, or fuse, the fibers together.

57b. Place one rubber stopper on the surface of each sieve, nest the sieves, and transfer the specimen to the surface of the upper (No. 10) sieve. Break up the specimen shape by pressing it against the sieve surface, using a flat face of the rubber stopper. Put the top cover and bottom receiver in place and shake either in a machine or by hand, with occasional inspection of the sieves, until substantially all the fiber has been broken up and collected in the bottom receiver.

57c. Carefully collect the particles on all three sieves and weigh.

58. *Calculations.*

58a. The percentage of shot shall be calculated as follows:

$$\text{Shot content} = \frac{\text{wt of particles retained on all sieves}}{\text{original wt of specimen}} \times 100.$$

59. *Report.*

59a. The report shall include the shot content expressed as percentage of the original weight.

## X. TEMPERATURE RESISTANCE: ALL MINERAL WOOL PRODUCTS

60. *Test specimen.*

60a. One specimen of designated thickness is required for each test. Each specimen shall have sufficient area to cover the heated testing plate or pipe mandrel.

61. *Apparatus.*

61a. Apparatus used shall be capable of uniformly maintaining the selected test temperature within ± 5 percent, or ± 25° F, whichever is less, on one face of the specimen.

61b. A gas or electrically heated plate, having dimensions not less than 12 in. by 12 in.

61c. A 4-ft-long steel pipe for testing pipe insulations, of a suitable size (preferably 3-in. steel pipe size) and equipped for internal heating by gas or electricity.

61d. At least five thermocouples mounted in the surface of the heated plate or pipe.

62. *Procedure.*

62a. The test temperature shall be specified prior to start of the test.

62b. Guard sections of the same insulating material shall be provided so that substantially the same temperature is maintained over the entire face of the test specimen.

62c. The specified test temperature shall be maintained continuously for 96 hr, then the apparatus shall be allowed to cool. The specimen shall then be removed and examined for evidence of physical and other changes.

62d. For specific uses, tests to determine the extent of changes in physical properties shall be made on the sample before and after heating when specified.

63. *Report.*

63a. The report shall include:

1. The temperature or temperatures at which tested.
2. Notes and observations on the behavior of the material during, and appearance after, the test.
3. Data of any supplementary test performed on the specimens before and after heating.

## XI. THERMAL CONDUCTIVITY

### (a) ALL MINERAL WOOL PRODUCTS EXCEPT BLANKET-TYPE AND MOLDED-TYPE PIPE INSULATION (THERMAL CONDUCTIVITY OF MATERIAL BY MEANS OF THE GUARDED HOT PLATE)

64. *Test specimens.*

64a. The test specified in paragraphs 66a through 66h shall be made on at least three test specimens to determine the thermal conductivity of an insulating material or product.

64b. Each sample shall be selected so as to provide two specimens as nearly identical as possible and of such size as to completely cover the heating unit. The specimens shall be of sufficient thickness to give a true average representation of the insulating material.

64c. The relationship between the maximum thickness of the test specimen used and the minimum dimensions of the guarded hot plate shall be as follows:

| *Maximum thickness of test specimen, inches* | *Minimum linear surface dimensions, inches* | |
|---|---|---|
| | *Central section* | *Guard section* |
| 1 | 4 | 1½ |
| 1½ | 8 | 2¼ |
| 2 | 12 | 3 |
| 4 | 12 | 6 |

64d. The sample chosen shall be a fair representative of typical or standard production of the insulation material. The surfaces of the materials shall be made as plane as possible, by sanding or otherwise, to effect intimate contact between the sample and the plates or thermocouple pad. The material shall be dried to constant weight at a temperature of 225° F.

65. *Apparatus.*

65a. The guarded hot plate apparatus is limited in application to thermal-conductivity tests between extreme temperatures of −50° F and +1,400° F, or between mean temperatures of approximately 0° F and 1,200° F. The construction of the apparatus shall comply with the requirements of the National Bureau of Standards plate, the National Research Council plate, or the Alundum plate. The National Bureau of Standards plate and the National Research Council plate are square and have metal surface plates. The Alundum plate is built with the heating coils molded into alundum cement so as to give a circular plate with alundum cement faces. The general features of the guarded hot plate are shown in figure 6. The plates are usually square, but round plates are occasionally used. The term "guarded hot plate" is applied to the entire assembled apparatus, including the heater unit, the cooling units, and the edge insulation. The heating unit consists of the central section of the heating unit and the guard section of the heating unit. The central section of the heating unit consists of a central heater and central surface plates. The guard section of the heating unit consists of one or more guard heaters and the guard surface plates. The surface plates are usually made of noncorrosive, highly conducting metal; however, the central section and the guard section of the heating unit may each be molded of alundum cement or other materials of low conductivity so as to include both the heaters and the sur-

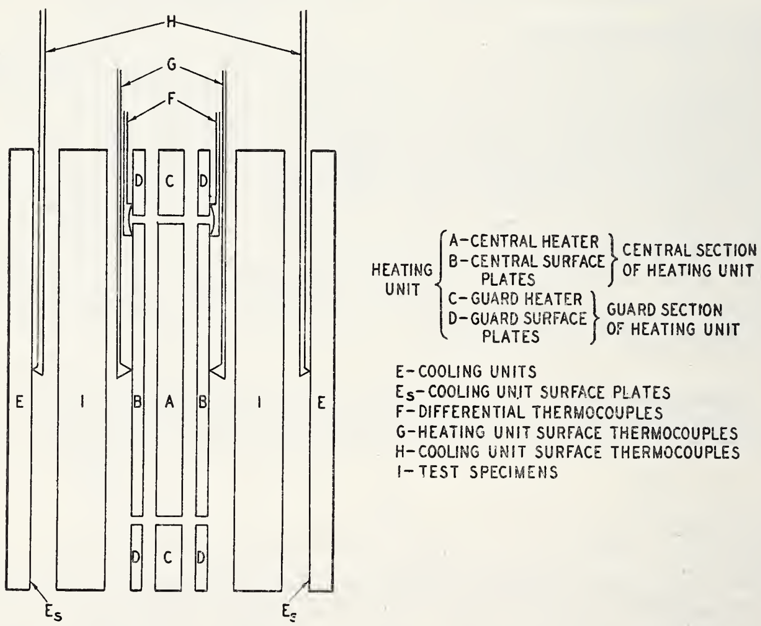



FIGURE 6.—*General features of the guarded hot plate used in determining the thermal conductivity of all mineral wool products except blanket-type and molded-type pipe insulation.*

face plates. The surfaces of the heater plates and cooling plates should be finished to as nearly a true plane as possible and should be checked periodically. Variations over 90 percent of the surface should be nil with maximum variations on any portion of the surface not exceeding 0.003 to 0.005 in.

65b. In the design of the guarded hot plate for testing materials for use in any particular temperature or conductivity range, due consideration shall be given to the materials used in the construction of the hot plate with respect to their performance at a temperature to which the plate will be subjected. Consideration shall also be given to the rate at which heat must be supplied and absorbed by the heater and the coolers in designing the electrical resistance and current carrying capacity of the heating element.

65c. Heating units having metallic surfaces shall have a definite separation or air gap not greater than 1/8 in. between the measuring area of the central surface plate and the guard surface plates. These plates shall have highly emissive surfaces. The separation between the main central section and the guard section of the heating units shall not exceed 3/4 in., and this separation is allowable only if the spacing bars on either side of the plate separation are heavy copper in order to distribute heat on the surface plates. In all other cases, the separation shall not exceed 1/8 in. The test area shall be calculated from the center of one separation to the center of the other separation across the central surface of the plate.

65d. The heater of the guarded hot plate shall be provided with at least two thermocouples on each face of the central surface plate, and at least two thermocouples on each face of the guard surface plate, located at opposite edges. These thermocouples may be read either individually to indicate any temperature difference that may exist between the central and guard surface plates or they may be connected differentially, and thus indicate such temperature difference directly. The differential method of connecting the center-to-guard thermocouples is the more sensitive, and is to be preferred. When the thermocouples are to be read individually, they may be peened, welded or soldered to the surface plates. When they are to be connected differentially, it is essential that they be electrically insulated from each other. This may be accomplished by installing the thermocouples in shallow grooves in the surface plates with an electrically insulating cement, in such a manner that the bead of each thermocouple is in the plane of the surface of the plate.

65e. The cooling units shall have the same surface dimensions as the heating units. They may consist of metallic plates cooled by fluid, electrically heated plates maintained at temperatures below that of the heating unit, or thermal insulation applied to the cool surface of the test specimen, depending on the mean temperature desired.

65f. The edge insulation may be of any convenient loose fill or blanket-type insulating material to reduce edge losses from the heater plate, test specimens and cooling plates. It shall be of such thickness that the resistance to edge losses shall be at least twice and preferably three or more times the thermal resistance of the specimen in the direction of the normal heat flow.

65g. The surface temperature of the test specimen may be determined either by means of the thermocouples mounted in the hot and cold plates or by thermocouples located in the surface of the specimen, depending on the nature of the material to be tested. For nonrigid materials that have a unit conductance of less than 1.0 Btu per sq ft, per hr, per °F, and that conform to the surfaces of the plates, the surface temperatures of the specimens shall be taken as those indicated by the thermocouples attached to the hot and cold surface plates. For this purpose, both the hot and cold plates shall each be supplied with at least two thermocouples mounted in the surfaces of the plates as described in paragraph 65d. Preferably, the thermocouples should be insulated from the plates and read differentially between the hot and cold plates, the surface temperatures of the specimen being taken as those of the plate surfaces in contact with it. For rigid materials that fail to conform to the surfaces of the plates, and for all materials having a unit conductance higher than 1.0 Btu per sq ft, per hr, per °F, separate surface thermocouples shall be used. These thermocouples shall be mounted on the surface of the specimen in any convenient manner suitable for the purpose, such that the thermocouple junction is flush with the surface of the specimen. When thermocouples are used in the surface of the specimen, there shall be placed between the surfaces of the specimen and the hot and cold plates a thermocouple pad consisting of blotting paper, asbestos paper, glass cloth, or other suitable materials, depending on the temperatures encountered. For nonrigid materials of low conductivity, the use of thermocouples in the plates is preferred; whereas for rigid materials and those of high conductivity, the use of surface thermocouples is preferred. In the intermediate range, the choice of method is left to the judgment of the operator.

65h. The thermocouples mounted in the surfaces of the plates shall be made of wire not larger than No. 23 AWG; those used as surface thermocouples shall be made of wire not larger than No. 29 AWG.

65i. A potentiometer having a sensitivity of 5 microvolts or less shall be used for all measurements of electromotive force.

66. *Procedure.*

66a. Tests shall be made on each set of specimens at three or more mean temperatures that will cover the range of temperatures over which the material is to be used. For any test, the temperature differences across the specimen shall be not less than 40° F. The above mean temperatures of the specimen shall differ from each other by at least 30° F.

66b. The atmosphere surrounding the test equipment shall have a dew point temperature not higher than the coolest part of any surface or material in, or forming a part of, the test apparatus.

66c. If the thermocouples mounted in the surfaces of the plates are used to determine surface temperature (par. 65g) the thickness of the test specimen shall be taken as the distance between the surfaces of the hot and cold plates when the specimen is in place in the apparatus. If separate surface thermocouples are used, the thickness of the test specimen shall be taken as the distance between the surfaces of the hot and cold plates when the specimen is in place in the apparatus, minus the thickness of the two thermocouple pads.

66d. The density of the insulating material shall be determined from the weight after drying and the volume occupied in the guarded hot plate immediately before the set of specimens is placed in the apparatus and brought up to temperature.

66e. The heating element of the central heater shall be supplied with electric energy regulated to give the desired temperature gradient through the test specimen and held constant within ± 1 percent, means being provided to measure this energy. Automatic regulation is recommended. Where automatic regulation is not available, the energy input shall be regulated by means of manual adjustment. The rate of electric energy input to the guard ring shall then be adjusted so that the maximum temperature difference (par. 66c) between the center and guard surface plates during the 5-hr test observation period shall not be greater than 0.75 percent of the average temperature drop through the two halves of the specimen, as determined by the differential thermocouples or the surface thermocouples. The average temperature difference between these surface plates during the test period shall be not greater than 0.2 percent of the temperature drop through the specimen.

66f. The cooling units shall be so adjusted that the temperature drops through the two test specimens shall not differ by more than one percent.

66g. After steady state has been reached, the test shall be continued with the necessary observations being made to determine temperature difference, center-to-guard thermal balance and heat input until successive observations made at intervals of not greater than 1 hr, over a period of 5 hr, give thermal-conductivity values that are constant to within 1 percent.

66h. Upon completion of all tests, the set of specimens shall be reweighed and the weight recorded.

67. *Calculations.*

67a. The density of the sample after drying, the moisture in the sample as received, and the moisture regain during test shall be calculated.

67b. Thermal conductivity shall be calculated by means of the equation

$$k=\frac{QL}{Ar\ (t_1-t_2)}=\frac{qL}{A\ (t_1-t_2)},$$

where

$k$ = thermal conductivity expressed in Btu in. per hr, per sq ft per °F
$Q$ = total quantity of heat transferred in Btu
$r$ = time in hr
$q$ = $Q/r$, rate of heat flow in Btu per hr
$A$ = actual area normal to the path of heat flow (flat surface) in sq ft
$t_1$ = temperature of the hot surface in °F
$t_2$ = temperature of the cold surface in °F
$L$ = length of path of heat flow (thickness) in in.

67c. The mean temperature of the insulation shall be taken as the value of $(t_1+t_2)/2$.

68. *Report.*

68a. The conductivity–mean-temperature relationship shall be obtained from a curve plotting the thermal conductivity versus mean temperature, and representing the average of the tests. The maximum deviation obtained from this average curve, and the mean temperature at which this maximum occurs shall be reported.

68b. Heat loss data for fabric reinforced blankets, boards, etc. shall be calculated and reported as thermal conductivity.

68c. The specimen thickness, weight and calculated density, moisture in sample as received, and moisture regain shall be stated.

### (b) 1. BLANKET-TYPE AND MOLDED-TYPE PIPE INSULATION (GUARDED END LOSSES)

69. *Test specimens.*

69a. The test specified in paragraphs 71a through 71k shall be made on at least three test specimens to determine the thermal conductivity of an insulating material or product.

69b. Each sample of blanket-type pipe insulation shall consist of two 24-in. lengths tightly butted together and securely wired. Each sample of molded-type pipe insulation shall consist of one 36-in section.

69c. The samples selected shall be such that a snug fit will be obtained without open joints when installed on the nominal 3-in. diameter test pipe.

70. *Apparatus.*

70a. The general construction of the apparatus to be used in testing pipe insulation is shown in figure 7. It consists of a 3-ft length of nominal 3-in. steel pipe having an actual OD of 3.5 in., ± 0.01 in. The test pipe shall be closed at the ends with caps of asbestos lumber and shall contain three heating coils connected in multiple and wound on a 2-in. enameled steel pipe or suitable refractory. The center heating element is wound over a 30-in. length of pipe, whereas each end heating element is wound over a 2¾-in. length of pipe. A gap shall be provided between the center and end sections of both the 2-in. and 3-in. pipes by sawing through the pipes, as shown in figure 7, section A-A. A variable resistance is placed in series with each of these coils to provide a means of regulating the heat supplied to each coil.

70b. A potentiometer having a sensitivity of at least 5 microvolts.

70c. A wattmeter or equivalent means of measuring heat input.

70d. Thermocouples to be mounted in the surface of the pipe shall be made of wires not larger than No. 23 AWG. Those used on the outside surface of the insulation shall be made of wire not larger than No. 29 AWG.

70e. A flexible steel tape graduated in 1/32 in.

71. *Test procedure.*

71a. Tests shall be made on each set of specimens at three or more mean temperatures that will cover the range of tempera-

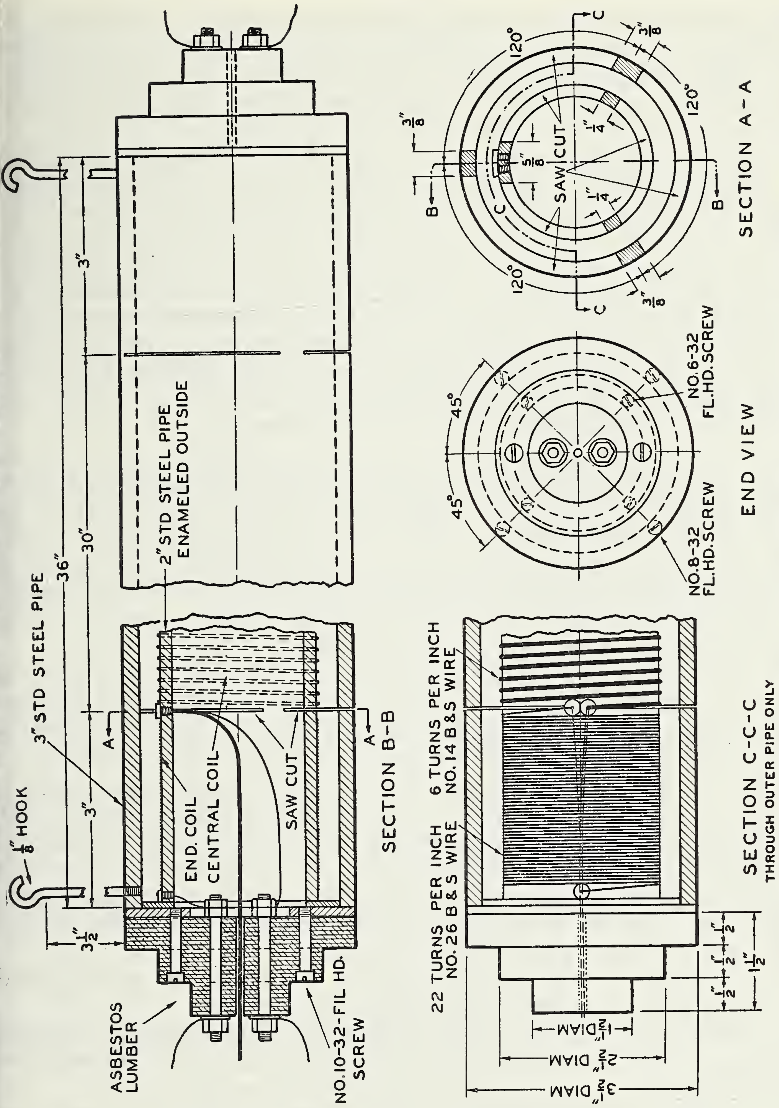



FIGURE 7.—*Test pipe apparatus for determining the thermal conductivity of blanket-type and molded-type pipe insulation.*

tures over which the material is to be used. For any test, the temperature differences across the specimen shall be not less than 40° F. The above mean temperatures of the specimen shall differ from each other by at least 30° F.

71b. The test samples shall be dried to constant weight at a temperature of 225° F immediately before the specimen is placed on the apparatus and brought up to temperature. The density of the specimen, expressed in lb/cu ft shall be computed from the weight after drying and from the volume occupied on the test pipe. The length of samples shall be determined to the nearest 1/16 in. The thickness shall be determined by taking one half the difference between the outside diameter of the insulation, as installed on the test pipe, and the outside diameter of the test pipe. The outside diameter of the insulation shall be calculated from the average of three circumferential readings measured to the nearest $\frac{1}{32}$ in. over the 30-in. test portion.

71c. Before applying the test sample to the horizontal test pipe, ten thermocouples, including at least one in each end section should be suitably spaced to give representative readings. They shall be inserted in the pipe by drilling holes slightly greater in diameter than the diameter of the bead of the junction and about $\frac{1}{16}$ in. deep. The junction is placed in this hole and fastened securely by peening the metal of the pipe against the thermocouple junction by means of a hammer and center punch. Preferably the couples in the end sections shall be connected differentially with the nearest couples in the adjacent center section, in which case they shall be electrically insulated from them.

71d. Care shall be taken to see that the junction of the thermocouples does not extend above the level of the pipe and the thermocouple wires do not touch each other at any point above the junction. The thermocouples shall be carefully inspected at least every third test and rewelded and reset as required. The covering shall be placed on the test pipe with longitudinal joint at the top of the pipe, so that when closed tightly the two edges of the covering enclose the thermocouple wires.

71e. The pipe insulation shall then be secured to the pipe in accordance with customary application practice for the specimen being tested. If the specimen does not fit the test pipe snugly without open joints, it shall be replaced with a new specimen.

71f. The thermocouples for the determination of the specimen surface temperature should be affixed to the outer surface with paper labels or other suitable means. At least four couples should be placed on the test section spaced 90° from each other in a vertical plane at a distance of from 4 in. to 6 in. from the center of the test section, the couples being placed at an angle of 45° from the horizontal and vertical positions.

71g. The crack between the ends of the covering and the end caps shall then be sealed with insulating cement.

71h. The temperature of the atmosphere surrounding the test equipment shall be maintained at a specified ambient temperature within 1° F.

71i. After the apparatus has been brought up to temperature the power input of each coil is adjusted until the temperature difference between the sections of pipe over the end coils and the center coil is not more than 0.75 percent of the temperature drop through the specimen. When this condition is reached it is assumed that the power supplied to the central coil is dissipated radially through the covering thus eliminating any further correction of end losses.

71j. After steady state has been reached, the test shall be continued with the necessary observations being made to determine temperature difference, center-to-guard thermal balance, and heat input until successive observations made at intervals of not greater than 1 hr, over a period of 5 hr, give thermal conductivity values that are constant to within 1 percent.

71k. Upon completion of all tests, the specimen shall be reweighed and the weight recorded.

72. *Calculations.*

72a. Thermal conductivity is computed as follows:

$$k = \frac{q r_1 \log_e \frac{(r_2)}{(r_1)}}{A(t_1 - t_2)},$$

in which

$k$ = thermal conductivity expressed in Btu in. per hr per sq ft per °F

$q$ = total rate of heat input in Btu per hr

$r_1$ = radius of the inside surface of the material which is assumed to be the same as the outside of the pipe (in.)

$r_2$ = radius of the outside surface of the material (in.)

$A$ = area of the pipe surface or the inside surface of the material surrounding the 30-in.-long center heating coil (sq ft)

$t_1$ = temperature of the inside surface of the material in °F (Assumed to be the same as the temperature of the heated pipe.)

$t_2$ = temperature of the outside surface of the material (°F).

72b. The mean temperature of the insulation shall be taken as the value of $(t_1 + t_2)/2$.

73. *Report.*—The report shall include all test data, calculations and the operator's notes.

73a. The conductivity–mean-temperature relationship shall be obtained from a curve plotting the thermal conductivity versus mean temperature, and representing the average of the tests. The maximum deviation obtained from this average curve, and the mean temperature at which the maximum occurs shall be reported.

73b. Heat loss data for blanket-type pipe insulation etc. composed predominantly of mineral wool shall be calculated and reported as thermal conductivity.

### (b) 2. BLANKET-TYPE AND MOLDED-TYPE PIPE INSULATION (ALTERNATE METHOD A—CALCULATED END LOSSES)

74. *Test specimens.*

74a. The test specified in paragraphs 76a through 76g shall be made on at least three test specimens to determine the thermal conductivity of an insulating material or product.

74b. Each specimen of blanket-type pipe insulation shall consist of three 24-in. lengths tightly butted together and securely wired. Each specimen of molded-type pipe insulation shall consist of two 36-in. lengths.

74c. The samples selected shall be such that a snug fit will be obtained without open joints when installed on the nominal 3-in.-diameter test pipe.

75. *Apparatus.*

75a. The test pipe consists of a thin 3½-in. OD seamless steel tube, of not over No. 11 gage thickness, 6 ft 0 in long. Inside the test pipe, and concentric with it, is to be placed the heater tube, which consists of a 3-in. OD seamless steel tube, of not over No. 11 gage thickness, and of the same length as the test pipe. Before inserting the heater tube, it is wrapped with suitable asbestos paper, upon which is wound noninductively the resistance wire which forms the heating element, and over this an additional layer or layers of asbestos paper so that the assembly will just fit the test pipe. The heater tube assembly is then inserted in the test pipe so that the ends are exactly even. The leads to the heater are brought out at one end, and the entire heater tube filled with loose mineral wool to minimize the effects of convection. A variable resistance is placed in series with the heating element as a means of regulating the heat supplied.

75b. Two pieces of suitable block insulation, 2-in. thick, one pierced for the leads to the heating element, of dimensions sufficient to cover the ends of the tubes and the insulation to be mounted on the test pipe; also sufficient insulating cement to hold the end pieces in place.

75c. A trestle or other means of supporting the assembly after the insulation is mounted.

75d. A potentiometer having a sensitivity of at least 5 microvolts.

75e. A wattmeter or equivalent means of measuring heat input.

75f. A flexible steel tape graduated in 1/32 in.

75g. Thermocouples to be mounted at the surface of the pipe shall be made of wires not larger than No. 23 AWG. Those used on the outside surface of the insulation shall be made of wire not larger than No. 29 AWG.

76. *Test Procedure.*

76a. Tests shall be made on each set of specimens at three or more mean temperatures that will cover the range of temperatures over which the material is to be used. For any test, the temperature differences across the specimen shall be not less than 40° F. The above mean temperatures of the specimen shall differ from each other by at least 30° F.

76b. The samples of 3-in. insulation shall be mounted as in practice over the entire length of the test pipe, taking care to butt the adjoining pieces closely. Preferably, the insulation should be mounted with the midpoint of one length at the midpoint of the length of test pipe, and the remaining equal space on each side of it taken up by two additional lengths in case of 24-in. pieces, or with two halves of length in the case of 36-in. pieces. If any of the samples of insulation do not fit the pipe snugly without open joints, it shall be replaced by a new piece. The ends of the insulation should be brought flush with the ends of the pipe and heater tube by cutting off any surplus or by filling a deficiency not over ¼ in. with insulating cement. The end pieces of block insulation described in par. 75b are then secured by cement and the whole supported in a horizontal position in such manner as not to distort the insulation.

76c. Before applying the test specimen, three pairs of the thermocouples shall be set on the pipe surface or alternately on the inside surface of the insulation, in the following locations, one of each pair being placed at the top of the pipe, and the other at the bottom in each case.

1. At the midpoint of the length of the test pipe.

2 and 3. At convenient equal distances, not less than 10 in. nor more than 32 in. on both sides of the midpoint of the test pipe.

Thermocouples may be set in place as described in par. 71c, or fastened to the inside surface of the insulation with extremely thin asbestos paper, pasted. Thermocouple leads should be run circumferentially at least 90° before being led to a convenient exit through the longitudinal joint of the insulation. Care shall be taken that thermocouple wires do not touch each other at any point above the junction. Thermocouples shall be inspected at least every third test and rewelded and reset as required.

76d. Thermocouples for the determination of the specimen surface temperature shall be affixed to such surface with paper labels or other suitable means. One pair of thermocouples, one at the top and the other at the bottom, shall be placed on the outside surface of the insulation at the midpoint of the length of the test pipe.

76e. The temperature of the atmosphere surrounding the test equipment shall be maintained at the specified ambient temperature within 2° F.

76f. After the apparatus has been brought up to temperature, and a steady state has been reached, the test shall be continued and the necessary observations made until successive observations made at intervals of not greater than 1 hr., over a period of 3 hr. give thermal conductivity values that are constant to within 2 percent.

76g. Upon completion of the tests, the specimen shall be reweighed and the weight recorded.

77. *Calculations.*

77a. A first approximation of the value of the thermal conductivity is first calculated from

$$k' = \frac{1.910q}{l(t_{1m}-t_2)} \log_e \frac{(r_2)}{(r_1)},$$

in which

$k'$ = first approximation of thermal conductivity expressed in Btu in. per hr per sq ft per °F

$q$ = total rate of heat input in Btu per hr

$l$ = length of test pipe in ft

$r_1$ = radius of inside surface of insulation, which is assumed to be the same as the outside of the test pipe (in.)

$r_2$ = radius of outside surface of insulation (in.)

$t_{1m}$ = observed temperature of inside surface of insulation in °F at the midsection of the pipe length. (Assumed to be the same as the temperature of the test pipe at that location.)

$t_2$ = observed temperature of outside surface of insulation at the midsection.

77b. The increment to be added to the observed temperature $t_{1m}$ is then calculated from

$$\Delta t_{1m} = \frac{t_{1m} - t_{1x}}{(\cosh x\sqrt{c}) - 1},$$

in which

$\Delta t_{1m}$ = increment to be added to $t_{1m}$ to allow for end losses

$t_{1x}$ = arithmetic mean of observed temperatures of inside surface of insulation in °F at points equidistant from and on either side of the midsection of the length of the test pipe

$x$ = distance of equidistant sections from the midsection of the pipe (in.), and

$$c = \frac{2\pi k'}{(f_1\lambda_1 + f_2\lambda_2)\ \log_e\ (r_2/r_1)},$$

in which

$f_1, f_2$ = area of cross section of test pipe and heating tube, respectively (sq in.).

$\lambda_1, \lambda_2$ = conductivities of metals used in test pipe and heating tube, respectively, expressed in Btu in. per hr per sq ft per °F.

77c. The final corrected value of the thermal conductivity of the insulation is

$$k = \frac{1.910q}{l(t_1 - t_2)} \log_e \frac{(r_2)}{(r_1)},$$

in which

$k$ = thermal conductivity expressed in Btu in. per hr per sq ft per °F

$t_1 = t_{1m} + \Delta t_{1m}$

$l$ = length of test pipe in ft.

77d. The mean temperature of the insulation shall be taken as the value of $(t_{1m} + t_2)/2$.

78. *Report.*

78a. The report shall include all test data, calculations, and the operator's notes.

78b. The conductivity–mean-temperature relationship shall be obtained from a curve plotting the thermal conductivity versus mean temperature, and representing the average of the tests. The maximum deviation obtained from this average curve, and the mean temperature at which the maximum occurs shall be reported.

78c. Heat loss data for blanket-type pipe insulation etc., composed predominantly of mineral wool shall be calculated and reported as thermal conductivity.

### (b) 3. BLANKET-TYPE AND MOLDED-TYPE PIPE INSULATION (ALTERNATE METHOD B—CALIBRATED END LOSSES)

79. *Test specimens.*

79a. The test specified in paragraphs 81a through 81f shall be made on at least three specimens to determine the thermal conductivity of an insulating material or product.

79b. Each specimen of blanket-type pipe insulation shall consist of three 24-in. lengths, which shall be tightly butted together and securely wired. Each specimen of molded-type pipe insulation shall consist of two 36-in. sections.

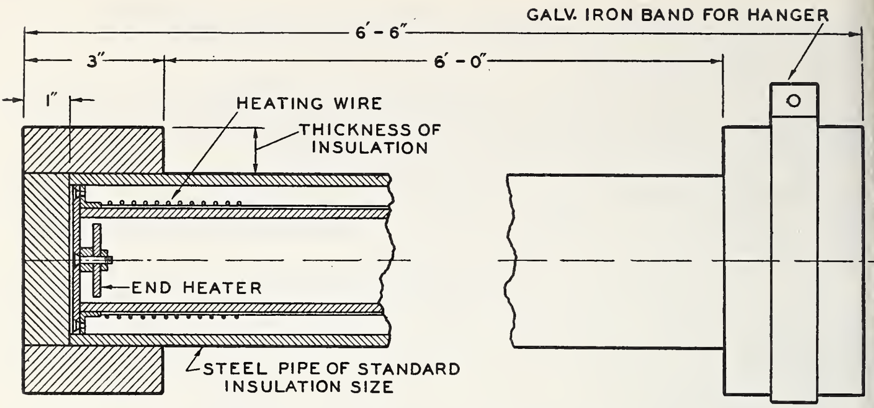
79c. The specimens selected shall be such that a snug fit will be obtained without open joints when installed on the steel test pipe. Unless otherwise specified, the test pipe shall be nominal 3-in. in diameter.

80. *Apparatus.*

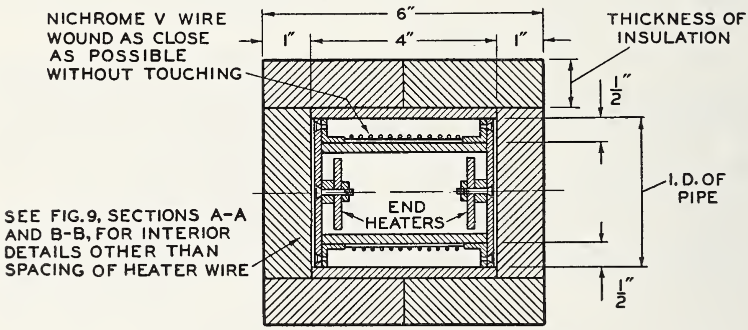
80a. The general construction of the apparatus is shown in figure 8. It consists of a standard steel pipe 6 ft 4 in. long with a 3 in. nominal ID to which insulation may be applied, a heater that is placed inside the pipe, and devices to measure the power consumed by the heater as well as to measure the temperature at various parts of the tester.

80b. The heater for the thermal-conductivity tester consists of three parts, a main heater and two supplementary end heaters. The main heater is wound on a steel pipe which is about 1½ in. smaller in diameter than the outside pipe to which the insulation is applied. The heater pipe is cut ⅜ in. shorter than the outside pipe, or 6 ft 3⅝ in. in length for the 6-ft tester. To each end of the heater pipe is attached, by means of small angles, a ⅛-in.-thick steel or asbestos-cement board disk of a diameter equal to the inside diameter of the outside pipe. These disks act as spacers to hold the heater pipe in the exact center of the tester pipe. Two layers of $\frac{1}{32}$-in.-thick asbestos paper are wrapped over the heater core. Over this assembly the heater of Nichrome V wire is space wound on approximately $\frac{3}{16}$-in. centers. The wire size will depend upon the length of wire used and also the temperature at which the insulation is to be tested. A total power output of about 800 watts is sufficient to maintain testers from a 2-in. to a 5-in. standard pipe size at 500° F hot surface when an average 1-in.-thick insulation is being tested.

80c. After the heater is wound the wire is held in place with applications of a mixture of silicate of soda and mica. This cement is applied in streaks about ½ in. wide and running the length of the pipe. The wire should be held down at about four or five places around the diameter of the pipe. The heater should not be coated completely as room must be allowed for expansion of the wire. An alternate plan for constructing the heater is to wind the heater wire in a bifilar fashion so that both the beginning and the ending of the heater winding are at the same end of the pipe. This system increases the chances of burnout due to a short but decreases the inductive effect caused by the iron core and allows both heater leads to be brought out at the same end of the tester.




ASSEMBLY (SEE FIG. 9 FOR DETAILS)




END CORRECTION APPARATUS. SECTIONAL VIEW

FIGURE 8.—*Test apparatus for determining the thermal conductivity of blanket-type and molded-type Pipe Insulation (alternate method B).*

80d. The supplementary end heaters are wound on small disks of asbestos-cement board and placed at each end of the pipe tester, as shown in the drawings. These heaters provide an extra source of heat to make up for that lost through the ends of the tester. This heater is wound with the same size of wire as the main heater and connected in series with the main heater. The wire density on the end heater is such that heat dissipation per sq in. is the same as from the surface of the heater.

80e. Calibrated end caps are used to compensate for the heat lost through the ends of the heater. The end caps, made of material similar to that being tested, extend 2 in. over each end of the pipe insulation tester. These end caps are made the same thickness as the insulation being tested and are calibrated on a heater, constructed in much the same manner as the regular pipe heater but having only a 4 in. length. (See fig. 8.) The two end caps are placed over the heater, cracks between the end caps

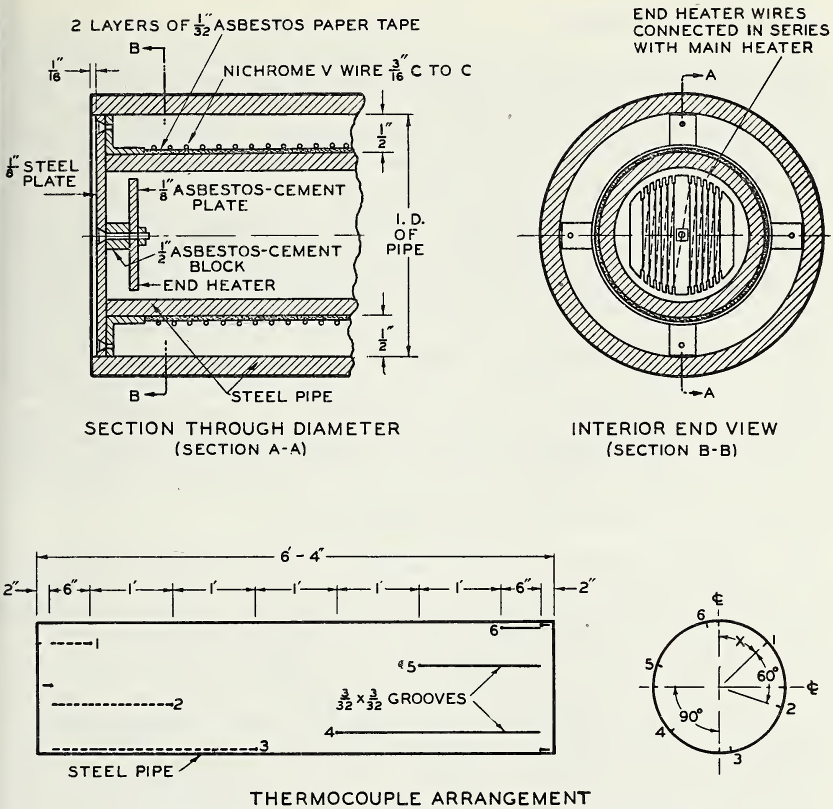



FIGURE 9.—*Details of test apparatus shown in figure 8.*

cemented with insulating cement, and power applied to the heater. After the apparatus has come to equilibrium the hot surface temperature of the end cap calibrator is recorded. Four thermocouples spaced 90° apart and placed in grooves located on the surface of the pipe are brought out between the end caps and are used to record this temperature. The temperature of the surrounding air is also recorded as well as the amount of power being consumed by the heater itself. A calibration curve of watt power versus temperature difference between the hot surface under the end cap and the surrounding air is then plotted. This curve is used to correct the total heat which is being lost through the end caps under the conditions at which they are being operated.

80f. A potentiometer having a sensitivity of at least 5 microvolts.

80g. A wattmeter or equivalent means of measuring heat input.

80h. Thermocouples to be mounted in the surface of the pipe shall be made of wires not larger than No. 23 AWG. Those used on the outside surface of the insulation shall be made of wires not larger than No. 29 AWG.

80i. Voltage regulator.

80j. A flexible steel tape graduated in 1/32 in.

81. *Test procedure.*

81a. Tests shall be made on each set of specimens at three or more mean temperatures that will cover the range of temperatures over which the material is to be used. For any test, the temperature differences across the specimen shall be not less than 40° F. The above mean temperatures of the specimen shall differ from each other by at least 30° F.

81b. The test samples shall be dried to constant weight at a temperature of 225° F immediately before the specimen is placed on the apparatus and brought up to temperature. The density of the specimen expressed in lb per cu ft shall be computed from the weight after drying and from the volume occupied on the test pipe. The length of samples shall be determined to the nearest $\frac{1}{16}$ in. The thickness shall be determined by taking one-half the difference between the outside diameter of the insulation, as installed on the test pipe, and the outside diameter of the test pipe. The outside diameter of the insulation shall be calculated from the average of six circumferential readings measured to the nearest $\frac{1}{32}$ in. over the 72-in. test portion.

81c. Before applying the test sample to the horizontal test pipe, six thermocouples connected in parallel shall be spaced at intervals of 60° around the circumference of the pipe and in the center of each foot of length along the test section of the pipe. These thermocouples shall be cemented with silicate of soda and mica into small grooves machined along the length of the pipe. Grooves $\frac{3}{32}$ in. by $\frac{3}{32}$ in. generally are of sufficient size; however, this is governed by the size of thermocouple wire used. Besides the six thermocouples used to measure the hot surface, two thermocouples are placed 1 in. from each end of the pipe. The end couples are spaced 180° apart and 90° from the corresponding thermocouple at the other end of the pipe. All thermocouples leave the pipe at a position 2 in. from the end between the test sample and the end cap. Aside from the thermocouples already described six thermocouples are placed on the surface of the insulation being tested directly opposite the corresponding thermocouple on the surface of the pipe. Each set of thermocouples are connected in parallel, i.e., the six couples measuring the pipe surface, the four couples measuring the temperature under the end caps, and the six measuring the outside temperature of the pipe insulation. Temperature readings of each individual thermocouple should be periodically checked.

81d. Power measurements may be made in several ways, depending on the equipment available. This may include either the ammeter, voltmeter system if direct current is used or a wattmeter system if either alternating current or direct current is used. Unless the wattmeter is of a compensated type, corrections must be made for the power consumed by the wattmeter itself. If the meters are removed from the circuit between readings, corrections must be made for the difference in power caused by the removal of the meters. Only the power consumed by the heater itself should be measured, which usually requires that potential leads must be taken from the equipment at the point the heater wires leave the tester.

81e. After the apparatus is completed, the end caps calibrated, and power and thermocouple connections made, the insulation to be tested is placed on the pipe and all joints sealed with insulating cement. The outside thermocouples are tied tightly to the surface of the insulation and power is applied to the heater. After the apparatus has come to equilibrium, temperature and power measurements are made at intervals of 1 hr for a period of at least 5 hr. During this time, the thermal conductivity, as calculated from the individual readings, shall be constant to within 1 percent.

81f. Upon completion of the test, the specimen shall be reweighed.

82. *Calculations.*

82a. Thermal conductivity is computed as follows:

$$k=\frac{q r_1 \log_e \frac{(r_2)}{(r_1)}}{A(t_1-t_2)},$$

in which

$k$ = thermal conductivity expressed in Btu in. per hr per sq ft per °F

$q$ = total rate of heat input in Btu per hr

$r_1$ = radius of the inside surface of the material, which is assumed to be the same as the outside of the pipe (in.)

$r_2$ = radius of the outside surface of the material (in.)

$A$ = area of the 72-in. test portion of the test pipe or the inside area of the test specimen surrounding this portion of the pipe

$t_1$ = temperature of the inside surface of the material in °F. (Assumed to be the same as the temperature of the heated pipe.)

$t_2$ = temperature of the outside surface of the material (°F).

82b. The mean temperature of the insulation shall be taken as the value of $(t_1+t_2)/2$.

83. *Report.*

83a. The conductivity–mean-temperature relationship shall be obtained from a curve plotting the thermal conductivity versus mean temperature, and representing the average of the tests. The maximum deviation obtained from this average curve, and the mean temperature at which the maximum occurs shall be reported.

83b. Heat-loss data for blanket-type pipe insulation, etc., composed predominantly of mineral wool shall be calculated and reported as thermal conductivity.

## WARRANTY

84. The following illustrates the manner in which a laboratory may certify complete compliance with the commercial standard. Laboratories complying with the methods of testing and reporting as recorded in the standard may be readily identified by the following statement on their reports.

> The ---------------------------------- warrants that the results given in this report were obtained in accordance with Industrial Mineral Wool Products, All Types—Testing and Reporting, Commercial Standard CS131–46, as issued by the National Bureau of Standards of the U. S. Department of Commerce.

## NOTES

85. *Compressive strength.*—The test method given for determining the compressive strength of mineral wool blocks, boards, and insulating cement is based on American Society for Testing Materials, Test for Compressive Strength of Preformed Block Type Thermal Insulating Materials (ASTM Designation: C165–45).

86. *Coverage insulating cement.*—The test method given for determining the coverage, volume change and density of mineral wool insulating cement is based on American Society for Testing Materials, Tentative Methods of Test for Covering Capacity and Volume Change Upon Drying of Thermal Insulating Materials (ASTM Designation: C166–41T).

87. *Density and thickness.*

87a. *Industrial batt, blanket, felt and blanket-type insulation.*—The test method given for determining the density and thickness of mineral wool batts, blankets, felt and blanket-type insulation is based on American Society for Testing Materials, Standard Methods of Test for Thickness and Density of Blanket-Type Thermal Insulating Materials (ASTM Designation: C167–44).

87b. *Block and board insulation.*—The test method given for determining the density of mineral wool blocks and board is based on American Society for Testing Materials, Emergency Specification for Preformed Block Thermal Insulation (ASTM Designation: ES–18).

87c. *Molded-type pipe insulation.*—The test method given for determining the density and thickness of mineral wool molded-type pipe insulation is based on American Society for Testing Materials, Emergency Specification for Preformed Pipe Covering Thermal Insulation (ASTM Designation: ES–17).

88. *Thermal conductivity.* The test method given for determining the thermal conductivity of all mineral wool products except blanket-type and molded-type pipe insulation is based on American Society for Testing Materials, Tentative Method of Test for Thermal Conductivity of Materials by Means of the Guarded Hot Plate (ASTM Designation: C177–42T).

## EFFECTIVE DATE

89. The standard is effective for new production from March 15, 1946.

## STANDING COMMITTEE

90. The following individuals comprise the membership of the standing committee, which is to review, prior to circulation for acceptance, revisions proposed to keep the standard abreast of progress. Each organization nominated its own representative. Comment concerning the standard and suggestions for revision may be addressed to any member of the committee or to the Division of Trade Standards, National Bureau of Standards, which acts as Secretary for the committee.

H. E. LEWIS (chairman), Owens-Corning Fiberglas Corporation, Nicholas Bldg., Toledo 1, Ohio.

S. C. FAY, Eagle-Picher Sales Co., American Building, Cincinnati 1, Ohio.

H. M. MARC, Philip Carey Manufacturing Co., Lockland, Cincinnati, Ohio.

C. B. EDGAR, H. M. Detrick Co., 104 Fox Street, Aurora, Ill.

W. R. DEGOWIN, Detroit Testing Laboratory, 554 Bagley Ave., Detroit 26, Mich.

T. SMITH TAYLOR, Director of Research, United States Testing Co., 1415 Park Ave., Hoboken, N. J.

R. S. DILL, Heat Transfer Section, National Bureau of Standards, Washington 25, D. C.

FRED W. WRIGHT, V. L. Nicholson Co., P. O. Box 156, Nashville, Tenn. (Representing Associated General Contractors of America, Inc.)

R. H. HEILMAN, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh 13, Pa.

## HISTORY OF PROJECT

On February 23, 1945, the Industrial Mineral Wool Institute requested the cooperation of the National Bureau of Standards in the establishment of a commercial standard for industrial mineral wool products, all types—testing and reporting. A preliminary draft of the proposed standard was submitted on April 12, 1945, to manufacturers and a large number of testing laboratories for their views and comment. All comment was carefully considered at a meeting held in Cleveland, Ohio, on June 15, 1945. An adjusted draft was then prepared and submitted on September 28, 1945, to technical and user organizations, testing laboratories, Government agencies, distributors, and manufacturers for further review and comment. The standard was then modified in accordance with the composite recommendations of those concerned and circulated on December 28, 1945, to the trade for written acceptance.

Upon receipt of acceptances in writing representing a satisfactory majority of the testing volume from laboratories engaged in the testing and reporting of industrial mineral wool products, the standard was promulgated on February 14, 1946, to become effective from March 15, 1946.

## ACCEPTANCE OF COMMERCIAL STANDARD

If acceptance has not previously been filed, this sheet properly filled in, signed, and returned will provide for the recording of your organization as an acceptor of this commercial standard.

Date______________________

Division of Trade Standards,
National Bureau of Standards,
Washington 25, D. C.

Gentlemen:

We believe that the Commercial Standard CS131-46, constitutes a useful standard of practice, and we individually plan to utilize it as far as practicable in the testing and reporting of industrial mineral wool products, with which we are directly concerned as a

producer [1] distributor [1] purchaser [1] testing laboratory [1]

We reserve the right to depart from it as we deem advisable.

We understand, of course, that only those tests which actually comply with the standard in all respects can be identified or reported as conforming thereto.

Signature of authorized officer_______________________________
(In ink)

(Kindly typewrite or print the following lines)

Name and title of above officer_______________________________

Organization _______________________________________
(Fill in exactly as it should be listed)

Street address _______________________________________

City, zone, and State_______________________________________

[1] Underscore which one. Please see that separate acceptances are filed for all subsidiary companies and affiliates which should be listed separately as acceptors. In the case of related interests, trade association, trade papers, etc., desiring to record their general support, the words "General Support" should be added after the signature.

## TO THE ACCEPTOR

The following statements answer the usual questions arising in connection with the acceptance and its significance:

1. *Enforcement.*—Commercial standards are commodity specifications voluntarily established by mutual consent of those concerned. They present a common basis of understanding between the producer, distributor, and consumer and should not be confused with any plan of governmental regulation or control. The United States Department of Commerce has no regulatory power in the enforcement of their provisions, but since they represent the will of the interested groups as a whole, their provisions through usage soon become established as trade customs, and are made effective through incorporation into sales contracts by means of labels, invoices and the like.

2. *The acceptor's responsibility.*—The purpose of commercial standards is to establish for specific commodities, nationally recognized grades or consumer criteria and the benefits therefrom will be measurable in direct proportion to their general recognition and actual use. Instances will occur when it may be necessary to deviate from the standard and the signing of an acceptance does not preclude such departures; however, such signature indicates an intention to follow the commercial standard where practicable, in the production, distribution, or consumption of the article in question.

3. *The Department's responsibility.*—The major function performed by the Department of Commerce in the voluntary establishment of commercial standards on a Nation-wide basis is fourfold: first, to act as an unbiased coordinator to bring all interested parties together for the mutually satisfactory adjustment of trade standards; second, to supply such assistance and advice as past experience with similar programs may suggest; third, to canvass and record the extent of acceptance and adherence to the standard on the part of producers, distributors, and users; and fourth, after acceptance, to publish and promulgate the standard for the information and guidance of buyers and sellers of the commodity.

4. *Announcement and promulgation.*—When the standard has been endorsed by a satisfactory majority of production or consumption in the absence of active, valid opposition, the success of the project is announced. If, however, in the opinion of the standing committee or the Department of Commerce, the support of any standard is inadequate, the right is reserved to withhold promulgation and publication.

# ACCEPTORS

The organizations listed below have individually accepted this standard for use as far as practicable in the testing and reporting of industrial mineral wool products. In accepting the standard they reserve the right to depart therefrom as they individually deem advisable. It is expected that testing laboratories which actually comply with the requirements of this standard in all respects will regularly identify or guarantee their test reports as conforming thereto, and that purchasers will require such specific evidence of conformity.

## ASSOCIATIONS

(GENERAL SUPPORT)

American Association of Engineers, Chicago, Ill.
American Society of Bakery Engineers, Chicago, Ill.
American Society of Refrigerating Engineers, New York, N. Y.
Associated General Contractors of America, Inc., The, Washington, D. C.
Dairymen's League Co-operative Association, Inc., New York, N. Y.
Industrial Mineral Wool Institute, New York, N. Y.

## FIRMS

Adams, Franklin O., Tampa, Fla.
Advanced Refrigeration, Inc., Atlanta, Ga.
Alexandria, City of, Power & Light Department, Alexandria, La.
Altfillisch, Charles, Decorah, Iowa.
American District Steam Co., N. Tonawanda, N. Y.
American Rock Wool Corporation, Chicago, Ill.
Arbogast & Bastian, Inc., Allentown, Pa.
Armour Research Foundation, Chicago, Ill.
Asbestos & Asphalt Products Co., Inc., South Bend, Ind.
Austin, Ennis R., South Bend, Ind.
Babcock & Wilcox Co., New York, N. Y.
Baldwin-Hill Co., Trenton, N. J.
Berger, F. E., & R. L. Kelley, Champaign, Ill.
Beuttler, William, Sioux City, Iowa.
Blithe, Wesley Lesher, Philadelphia, Pa.
Boehm, George A., New York, N. Y.
Borrowman, George, Chicago, Ill.
Bovard, William R., Kansas City, Mo. (General support).
Bowser-Morner Testing Laboratories, Dayton, Ohio.
Brazer, Clarence W., New York, N. Y.
Brewer & Gardner, Philadelphia, Pa.
Brooks-Borg, Architects-Engineers, Des Moines, Iowa.
Brust & Brust, Milwaukee, Wis.
Bruce Co., E. L., Memphis, Tenn.
Bucky, Fred W., Jr., Jacksonville, Fla.
Buechner & Orth, St. Paul, Minn. (General support).
Caloric Gas Stove Works, Philadelphia, Pa.
Camlet, J. Thomas, Passaic, N. J.
Campbell Soup Co., Camden, N. J.
Cannon & Mullen, Salt Lake City, Utah.
Carey Manufacturing Co., The Philip, Lockland, Cincinnati, Ohio.
Carney Co., The,—Carney Rockwool Co., Mankato, Minn.
Carney Rockwool Co., Minneapoiis, Minn.
Celanese Corporation of America, Cumberland, Md.
Certain-teed Products Corporation, Chicago, Ill.
Chicago, Milwaukee, St. Paul & Pacific Railroad Co., Milwaukee, Wis.
Coleman & Co., W. B., Philadelphia, Pa.
Colorado Insulating Co., Denver, Colo.
Connecticut Light & Power Co., The, Waterbury, Conn.
Conrad & Cummings, Binghamton, N. Y.
Consolidated Gas, Electric Light & Power Co. of Baltimore, Baltimore, Md.
Consolidated Vultee Aircraft Corporation, Nashville, Tenn.
Conwell & Co., E. L., Philadelphia, Pa.
Coolidge, Shepley, Bulfinch & Abbott, Boston, Mass.
Corlett, Will G., & Arthur W. Anderson, Oakland, Calif.
Corn Products Refining Co., Chicago, Ill.
Corson, Inc., G. & W. H., Plymouth Meeting, Pa.
Cram & Ferguson, Boston, Mass.
Crosley Corporation, The, Cincinnati, Ohio.
Dallas Power & Light Co., Dallas, Tex.
Danville State Hospital, Danville, Pa.
Deere & Co., Moline, Ill.
DeJarnette, Charles Wagner, Des Moines, Iowa.
Detrick Co., M. H., Aurora, Ill.
Detroit Ice Machine Co., Detroit, Mich. (General support).
Detroit Testing Laboratory, The, Detroit, Mich.
Doyle & Russell, Richmond, Va.
Eagle Home Insulation Co., Lincoln, Nebr.
Eagle-Picher Co., New York, N. Y.
Eagle-Picher Sales Co., The, Cincinnati, Ohio.
Ekroth Laboratories, Inc., Brooklyn, N. Y.
El Paso Testing Laboratories, El Paso, Tex.
English, Miller & Hockett, Hutchinson, Kans.
Evans Products Co., Western Division, Coos Bay, Oreg.
Federal Building Material Co., Tulsa, Okla.
Federal Portland Cement Co., Inc., The, Buffalo, N. Y.
Finck Laboratories, The J. L., Brooklyn, N. Y.
Flannagan, Eric G., Henderson, N. C.
Florida, University of, Architects to the Board of Control, Gainesville, Fla.
Foster Co., L. A., St. Louis, Mo.
Foster Wheeler Corporation, New York, N. Y.
Froehling & Robertson, Inc., Richmond, Va.
Funk & Co., H. B., Brunswick, Md.
Gall, Harry L. C., New York, N. Y.
Ganteaume & McMullen, Boston, Mass.
Glassboro Cold Storage Corporation, Glassboro, N. J.
Gotshall Co., G. H., Detroit, Mich.
Green Fire Brick Co., A. P., Mexico, Mo.
Gypsum Lime & Alabastine, Canada, Ltd., Toronto, Canada.
Hahn, Stanley W., South Pasadena, Calif.
Hanks, Inc., Abbott A., San Francisco, Calif.
Haralson & Mott, Fort Smith, Ark.
Harris Laboratories, Lincoln, Nebr.
Hasness, Carlisle D., Harrisburg, Pa.
Hastings, City of, Water & Light Department, Hastings, Nebr.
Hausman, N. W., Glen Cove, N. Y.
Helfensteller, Hirsch & Watson, St. Louis, Mo.
Hodgdon & Son, Charles, San Gabriel, Calif.
Hoener, P. John, St. Louis, Mo.
Holsman & Holsman, Chicago, Ill.
Hooker Electrochemical Co., Niagara Falls, N. Y.
Hope, Frank L., Jr., San Diego, Calif.
Houston Laboratories, Houston, Tex.
Industrial Insulators, The, Houston, Tex.
Insulation Products, Ltd., Toronto, Ont., Canada.
International Heater Co., Utica, N. Y.

International Salt Co., Inc., Ithaca, N. Y.
Ivey, Inc., Edwin J., Seattle, Wash.
Kaelber & Waasdorp, Rochester, N. Y.
Kahn & Jacobs, New York, N. Y.
Kansas State College, Department of Architecture, Manhattan, Kans.
Karno-Smith Co., Trenton, N. J.
Kellogg Co., The M. W., New York, N. Y.
Keystone Steel & Wire Co., Peoria, Ill.
Kohler Co., Kohler, Wis.
Latenser & Sons, John, Omaha, Nebr.
Laucks Laboratories, Inc., Seattle, Wash.
Law, Law, Potter & Nystrom, Madison, Wis.
Levy, Will, St. Louis, Mo.
Lockhart Power Co., Lockhart, S. C.
Lucht, Harry, West Englewood, N. J.
Manitowoc Refrigerating Co., Manitowoc, Wis.
Mann & Co., Hutchinson, Kans.
Marathon Corporation, Rothschild, Wis.
Mason & Co., George D., Detroit, Mich.
Massena & duPont, Inc., Wilmington, Del.
Materiales Aislantes, S. A., Monterrey, N. L., Mexico.
McCallum Inspection Co., Norfolk, Va.
Meridian Chemical Laboratories, Meridian, Miss.
Michigan College of Mining & Technology, Houghton, Mich.
Minnesota Testing Laboratories, Inc., Duluth, Minn.
Minnesota, University of, Minneapolis, Minn.
Mock & Morrison, Tacoma, Wash.
Mooser, William, San Francisco, Calif.
Morell, N. L., Bethlehem, Pa.
Mueller, Hair & Hetterich, Hamilton, Ohio.
Muhlenberg Bros., Reading, Pa.
National Gypsum Co., Buffalo, N. Y.
National Tube Co., Lorain, Ohio.
Nelson, Albert L., St. Louis, Mo.
New Hampshire Highway Department Laboratory, Concord, N. H.
Newton Falls Paper Mill, Newton Falls, N. Y.
Nordberg Manufacturing Co., Milwaukee, Wis.
Norfolk Testing Laboratory, Norfolk, Va. (General support).
North Carolina Pulp Co., Plymouth, N. C.
North Dakota Mill & Elevator, Grand Forks, N. Dak.
Northwest Baker Ice Mach. Co., Seattle, Wash.
Officer, Gwynn, Berkeley, Calif.
Ohio University, Athens, Ohio.
Oklahoma A. & M. College, Civil Engineering Department, Stillwater, Okla.
Oklahoma Geological Survey, Norman, Okla.
Oklahoma, University of, Norman, Okla.
Orthmann Laboratories, Inc., The, Milwaukee, Wis.
Oregon State College, Corvallis, Oreg.
Owens Corning Fiberglas Corporation, Toledo, Ohio.
Pabst Air Conditioning Corporation, Brooklyn, N. Y.
Pacific Power & Light Co., Portland, Oreg. (General support).
Pehrson & Associates, G. A., Spokane, Wash.
Penniman & Browne, Baltimore, Md.
Pet Milk Co., St. Louis, Mo.
Philadelphia, City of, Bureau of Water, Department of Public Works, Philadelphia, Pa.
Pittsburgh, City of, Bureau of Tests, D. P. W., Pittsburgh, Pa.
Post Power Supply Co., Appleton, Wis.
Pusey & Jones Corporation, The, Wilmington, Del.
Refrigeration Economics Co., Inc., Canton, Ohio.
Reilly-Benton Co., Inc., The, New Orleans, La.
Rensselaer Polytechnic Institute, Department of Architecture, Troy, N. Y.
Resnikoff, Abraham, New York, N. Y.
Rhodes, Harry A., Rensselaer, N. Y.
Riley Stoker Corporation, Worcester, Mass.
Riverton Lime & Stone Co., Inc., Riverton, Va.
Robert & Co., Inc., Atlanta, Ga.
Rosenblatt & Hunt, Inc., Charleston, W. Va.
Schmidt, Garden & Erikson, Chicago, Ill.
Schulzke, William H., Moline, Ill.
Seeger-Sunbeam Corporation, St. Paul, Minn.
Shaver, Chas. W., Salina, Kans.
Shilstone Testing Laboratory, New Orleans, La.
Sidells, Philpott & Lawrence, Warren, Ohio.
Skelly Oil Co., Tulsa, Okla. (General support).
Sleeper, Harold R., New York, N. Y.
Sommer Chemicals Laboratories, Inc., Milwaukee, Wis.
South Jersey Insulating Co., Camden, N. J.
Southern Alkali Corporation, Corpus Christi, Tex.
Southern Pacific Co., San Francisco, Calif.
Spreckels Sugar Co., San Francisco, Calif.
Spun Rock Wools, Ltd., Thorold, Ontario, Canada.
Staley Manufacturing Co., A. E., Decatur, Ill.
Standard Brands, Inc., New York, N. Y.
Standard Oil Development Co., Elizabeth, N. J.
Staub & Rather, Houston, Tex.
Sterling Co., Paul M., New York, N. Y.
Stoetzel, Ralph, Chicago, Ill.
Stravs, Carl B., Minneapolis, Minn.
Streeter, D. D., Brooklyn, N. Y.
Sun Oil Co., Philadelphia, Pa.
Taylor, T. Smith, Caldwell, N. J.
Tennessee Products Corporation, Nashville, Tenn.
Thomas Air Conditioning, Inc., Norfolk, Va.
Thompson & Lichtner Co., Inc., The, Boston, Mass.
Thorne, Henry Calder, Ithaca, N. Y.
Toronto, University of, Toronto, Ont., Canada.
Twin City Testing & Engineering Laboratory, St. Paul, Minn.
Twining Laboratories, The, Fresno, Calif.
Union Asbestos & Rubber Co., Cicero, Ill.
United States Mineral Wool Co., Chicago, Ill.
United States Testing Co., Inc., Hoboken, N. J. (General support).
Vander Straten, Richard, San Antonio, Tex.
Villanova College, Villanova, Pa.
Virginia Polytechnic Institute, Department of Architectural Engineering, Blacksburg, Va. (General support).
Virginian Railway Co., The, Princeton, W. Va.
Vogel, Willis A., Toledo, Ohio.
Voorhees, Walker, Foley & Smith, New York, N. Y.
Walsh & Co., Inc., J. A., Houston, Tex.
Ware & McClenahan, Salt Lake City, Utah.
Wayne Laboratories, The, Waynesboro, Pa.
Weber Insulations, Inc., East Chicago, Ind.
Welch, Carroll E., Huntington, N. Y.
Western Electric Co., Inc., New York, N. Y.
Willatsen, Andrew, Seattle, Wash.
Williams Inspection Co., A. W., Mobile, Ala.
Williams Laboratories, The Bruce, Joplin, Mo.
Willson, Fred F., Bozeman, Mont.
Willys-Overland Motors, Inc., Toledo, Ohio.
Wisconsin, University of, Heat & Water Department, Madison, Wis.
Woolsulate, Inc., Salt Lake City, Utah, and Midvale, Utah.
Zimmerman, A. C., Pasadena, Calif.

U. S. GOVERNMENT

Agriculture, U. S. Department of, Washington, D. C.
Civil Aeronautics Administration, Washington, D. C.
Federal Works Agency, Public Buildings Administration, Washington, D. C. (General support).
Interior, Department of the, Office of Indian Affairs, Chicago, Ill.
Interior, Department of the, Bureau of Mines, Washington, D. C. (General support).
Justice, Department of, Bureau of Prisons, Construction Division, Washington, D. C.
Justice, Department of, United States Penitentiary, Lewisburg, Pa.
War Department, Washington, D. C.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1946—694860