NBSIR 79-1930

Interlaboratory Evaluation of the Cyclone Settled Density Test for Cellulosic Loose Fill Insulation

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U.S. DEPARTMENT OF COMMERCE

Luther H. Hodges, Jr., ***Under Secretary***

Jordan J. Baruch, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

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INTERLABORATORY EVALUATION OF THE CYCLONE SETTLED DENSITY TEST FOR CELLULOSIC LOOSE FILL INSULATION

J. Randall Lawson

Abstract

The cyclone settled density test for cellulosic loose fill insulation was evaluated in an interlaboratory test program. Seven laboratories tested seven cellulosic loose fill insulations manufactured for the home insulation market. The participating laboratories were surveyed to evaluate the test apparatus and test methodology used at each location. It was concluded that none of the apparatus used in the program completely met the prescribed dimensional requirements for the test. However, statistical analysis of the test results showed that the repeatability coefficient of variation ranged from 2.3 to 3.7 percent with a median of 2.9 percent, and the reproducibility coefficient of variation ranged from 4.4 to 9.9 percent with a median of 8.4 percent. The median difference in density for the materials was 28 percent when blown density was compared to settled density. This study indicated that there is reasonable assurance that test results on the same material obtained at one laboratory can be reproduced in one of the other laboratories.

Key words: Cellulosic thermal insulation; cyclone settled density test; precision estimates.

1. INTRODUCTION

On March 8, 1979, the Consumer Product Safety Commission (CPSC) published in the Federal Register a proposed safety standard for cellulosic loose fill insulation [1][1]. This standard proposed a smoldering combustion test and a test for corrosiveness. In order to conduct these tests, the settled density for each cellulosic insulation must be determined. It was reported by Gross [2] and others that the smoldering tendency of cellulosic insulation materials was

[1]Numbers in brackets refer to the literature references listed at the end of this report.

sensitive to changes in density, and the resulting test procedures were designed to evaluate the materials at a settled density. Therefore, a test for determining settled density was also included in the standard. The procedure followed in this study was based on the March 8 proposed standard and had not been thoroughly researched to define effects of variables in the procedure or equipment. Subsequently, changes were made in the final published version of the standard [3]. See the revised test procedure in appendix A.

The objective of this project was to determine precision estimates for repeatability[2] and reproducibility[3] for the cyclone settled density test.

2. TEST METHOD

2.1 Apparatus

The primary apparatus for the cyclone settled density test consists of a 30.5 cm (12 in) diameter cyclone funnel that tapers to 11.4 cm (4-1/2 in) at the bottom. The total height of the cyclone assembly is 43.5 cm (17-1/8 in) (see figures 1 and 2). The cyclone is attached to the top of a fill chamber 45.7 cm (18 in) high by 38.1 cm (15 in) wide by 38.1 cm (15 in) deep. The fill chamber has a rigid, removable, transparent window on its front side. This window is used by the operator for placing the specimen container into the fill chamber, viewing the filling process, and removing the specimen container after it is filled.

An open top glass straight-sided specimen collection container of approximately 15 cm (5.9 in) diameter with a total volume of 3.5 to 5.0 liters (210 to 310 cu in) is placed in the fill chamber directly below the cyclone spout. Two blowers with connecting hose are attached to the fill chamber. One blower delivers insulation to the cyclone, and the other is used to remove excess insulation and maintain a relatively even pressure in the fill chamber. The speed of each blower is controlled by a variable transformer at a no load voltage of 40 volts.

A sieve shaker that is capable of shaking 4.5 kg (10 lbs) of weight with vertical motion of 0.5 g root mean square (RMS) acceleration at an approximate

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[2]Repeatability precision - repeatability or within-laboratory precision is defined in terms of the variability between test results obtained <u>in the same laboratory</u> on the same material [4].

[3]Reproducibility precision - reproducibility or between-laboratory precision is defined in terms of the variability <u>between test results</u> obtained <u>in different laboratories</u> on the same material [4].

frequency of 9 Hertz (Hz) and a displacement of approximately 1.2 cm (15/32 in) is used to shake the insulation after it has been blown.

2.2 Specimen Conditioning

Test specimens are conditioned to equilibrium at 21 ± 5°C (70 ± 9°F) and 50 ± 5% relative humidity. A net weight change of less than 1 percent of the specimen in two consecutive weighings with two hours between each weighing constitutes the attainment of equilibrium [1,4].

2.3 Test Procedure

After a specimen has been conditioned, it is ready to be tested. An empty insulation specimen container is weighed and placed in the fill chamber, centered under the cyclone spout. The blowers are started, and when they reach steady operating conditions, insulation is picked up by the supply hose and delivered to the fill chamber. The operator observes the filling of the specimen container and shuts the blowers off when the container is full. The container is removed from the fill chamber and the excess material extending above the container top is gently skimmed off. The filled container is weighed, covered, and placed in the shaker. The specimen and container are shaken for 5 minutes ± 15 seconds. The specimen container is removed from the shaker, uncovered, and a flat-rigid disc weighing 75 ± 5 g (2.7 ± 0.18 oz) which fits loosely inside the specimen container is placed on top of the specimen. The distance from the bottom of the specimen container to the bottom edge of the disc is measured. This measurement when combined with the inside area of the container provides a measure of the settled volume. The settled density is determined by dividing the specimen weight by the measured settled volume. The settled density of a material is considered the average of four settled density tests.

3. PARTICIPANTS

Seven laboratories, listed below, participated in this interlaboratory test program. Three of the laboratories were associated with cellulosic insulation manufacturers. Three laboratories were government laboratories and one was a commercial testing laboratory. Prior experience with the test procedure in the laboratories ranged from one to four months.

Certified Testing Laboratories, Inc.
Dalton, Georgia

Consumer Product Safety Commission
Engineering Laboratory
Bethesda, Maryland

Diversified Insulation Inc.
Hamel, Minnesota

Energy Guard Manufacturing Company
Erie, Michigan

General Services Administration
Research and Development FREL
Washington, D.C.

Lane Instrument Company
El Cajon, California

Oak Ridge National Laboratory
Union Carbide Corporation, Nuclear Division
Oak Ridge, Tennessee

4. LABORATORY SURVEY

A survey was conducted to evaluate the test apparatus and test methodology followed at each of the participating laboratories. This was done to identify differences in equipment and procedures that could cause test result variations. The laboratory survey data are shown in table 1. As indicated by the asterisks, no laboratory totally met the standard requirements. Dimensional variations from the standard were apparent for the inside diameter of the specimen container, the size of the fill chamber, the connecting hose lengths, the shaker displacement, and the cyclone construction. Other variations from the standard included a plastic specimen container, flared sides on a specimen container, excessive disc weight, and high conditioning relative humidity.

5. MATERIALS AND SAMPLE PREPARATION

Seven cellulosic loose fill insulation materials were obtained from seven different manufacturers. All of the products were manufactured for use as home insulation. The main component for five of the products was ground waste paper. The main components for the remaining products were cotton and ground wood, respectively.

Laboratory samples for each product were prepared by blending two bags of insulation that were taken consecutively from the manufacturer's production line. This was accomplished by placing the insulation from two bags in a pile. The pile was then raked, repiled, quartered, repiled and then raked again. Each sample lot was blended four times using the above procedure. After a lot was blended, a 2.3 kg (5.0 lb) sample was taken and placed in a plastic bag for each laboratory. The bags were sealed and tagged with a code letter. Samples grouped for each laboratory were then boxed and shipped.

6. EXPERIMENTAL DESIGN

The cellulosic loose fill insulation materials were shipped to each participating laboratory. A letter was also sent to each participant providing detailed instructions concerning the requirements of the interlaboratory test program. A copy of the test procedure as published in the March 8, 1979 Federal Register was enclosed with the letter.

The instructions requested that the samples be conditioned and tested in accordance with the test procedure as presented in the proposed CPSC standard. One modification was made to the test procedure. It was found that different laboratories were using specimen collection containers that varied in volume and height. This resulted in variations in the distance between the cyclone outlet and the top of the specimen container. In order to standardize this distance, it was requested that each laboratory position their collection container to provide a 50 to 56 mm (2.0 to 2.3 in) distance between the cyclone outlet and the top of the container. It was also requested that the testing be completed and the data sent to NBS by May 11, 1979.

7. TEST RESULTS AND DISCUSSION

Each laboratory conducted the cyclone settled density test on seven different cellulosic loose fill insulation materials. Four replicate tests were run on each sample as specified by the proposed standard.

The statistical methods used in the analysis of the test results are found in the "Tentative Recommended Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods" which was prepared by ASTM Committee E 11 [4]. A summary of the procedure is presented in reference [5].

Table 2 shows a tabulation of the settled density test results as received from each laboratory. The test results are given in SI (International System of Units) as well as English units. As shown by the asterisks in data cell 3P, the insulation clogged the blower causing stoppages. As a result of this report, the data contained within that cell were not used in the analysis. Also, laboratory number three reported that it was unable to maintain the specified relative humidity when conditioning the test specimens. All of their test specimens were conditioned at 60 percent relative humidity.

Table 3 presents the settled density cell averages ordered from the lowest to the highest density, and column averages are located at the bottom of the table. The average settled density for these materials ranged from 33.4 to 62.2 kg/m^3 (2.08 to 3.88 lb/ft^3). On the average, the results reported by laboratory number two were somewhat lower than the results reported by the other laboratories.

A comparison of blown density versus settled density is shown in table 4. The differences in density for the seven materials ranged from 21 to 46 percent with a median of 28 percent which represents a significant increase. It should be noted that the objectives of this study did not include correlating the results of this settled density test procedure with actual settled densities that may be found in the field.

Table 5 exhibits data cell standard deviations and the pooled standard deviation for each material. The pooled standard deviation is also shown in table 6 as the repeatability standard deviation. Table 6 presents precision estimates for repeatability and reproducibility. As shown, the repeatability coefficient of variation for the test ranged from 2.3 to 3.7 with a median of 2.9 percent. The reproducibility coefficient of variation ranged from 4.4 to 9.9 with a median of 8.4 percent. The results indicate relatively good repeatability and reproducibility. Even with the variations in the test apparatus and test procedure as noted in section 4, it is apparent that the test method provides relatively good assurance that test results on the same material obtained at one laboratory can be reasonably reproduced in one of the other laboratories.

8. SUMMARY AND CONCLUSIONS

Seven laboratories participated in an interlaboratory test program designed to determine the repeatability and reproducibility of the proposed CPSC cyclone settled density test for cellulosic loose fill insulation. The test procedure was published in the March 8, 1979 Federal Register. Seven cellulosic insulation materials produced for the home insulation market were tested.

A laboratory survey was conducted to evaluate the test apparatus and methodology used by each participating laboratory. A number of deviations in the test apparatus and use of the test procedure were noted.

Statistical analysis of the data received from the laboratories showed a median difference of 28 percent between blown density and settled density. The repeatability coefficient of variation ranged from 2.3 to 3.7 percent with a median of 2.9 percent, and the reproducibility coefficient of variation ranged from 4.4 to 9.9 percent with a median of 8.4 percent. These results indicate that there is a reasonable assurance that test results on the same material obtained at one laboratory can be reproduced in one of the other laboratories.

9. ACKNOWLEDGMENTS

Appreciation is extended to the laboratories that conducted the testing without compensation, and to the insulation manufacturers that provided the materials. Mr. Bernard Schwartz of the Consumer Product Safety Commission and the field offices assisted in obtaining materials. Statistical consultation was provided by Mrs. Mary G. Natrella, Statistical Engineering Division, National Bureau of Standards. Mr. Sanford Davis, Furnishings Flammability Research, National Bureau of Standards, provided assistance throughout the project. Messrs. Tom Prather and Dennis Sullivan of the National Bureau of Standards carried out initial specimen preparation.

10. REFERENCES

[1] Interim Safety Standard for Cellulose Insulation, Consumer Product Safety Commission, Federal Register, Vol. 44, No. 47, March 8, 1979.

[2] Gross, Daniel, A preliminary study of the fire safety of thermal insulation for use in attics or enclosed spaces in residential housing, Nat. Bur. Stand. (U.S.), NBSIR 78-1497 (July 1978).

[3] Interim Safety Standard for Cellulose Insulation, Consumer Product Safety Commission, Federal Register, Vol. 44, No. 131, July 6, 1979.

[4] Tentative Recommended Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods, ASTM Committee E 11, American Society for Testing and Materials, Philadelphia, Pa. (1979).

[5] Lawson, J. Randall, Interlaboratory evaluation of the attic floor radiant panel test and smoldering combustion test for cellulose thermal insulation, Nat. Bur. Stand. (U.S.), NBSIR 79-1588 (February 1979).

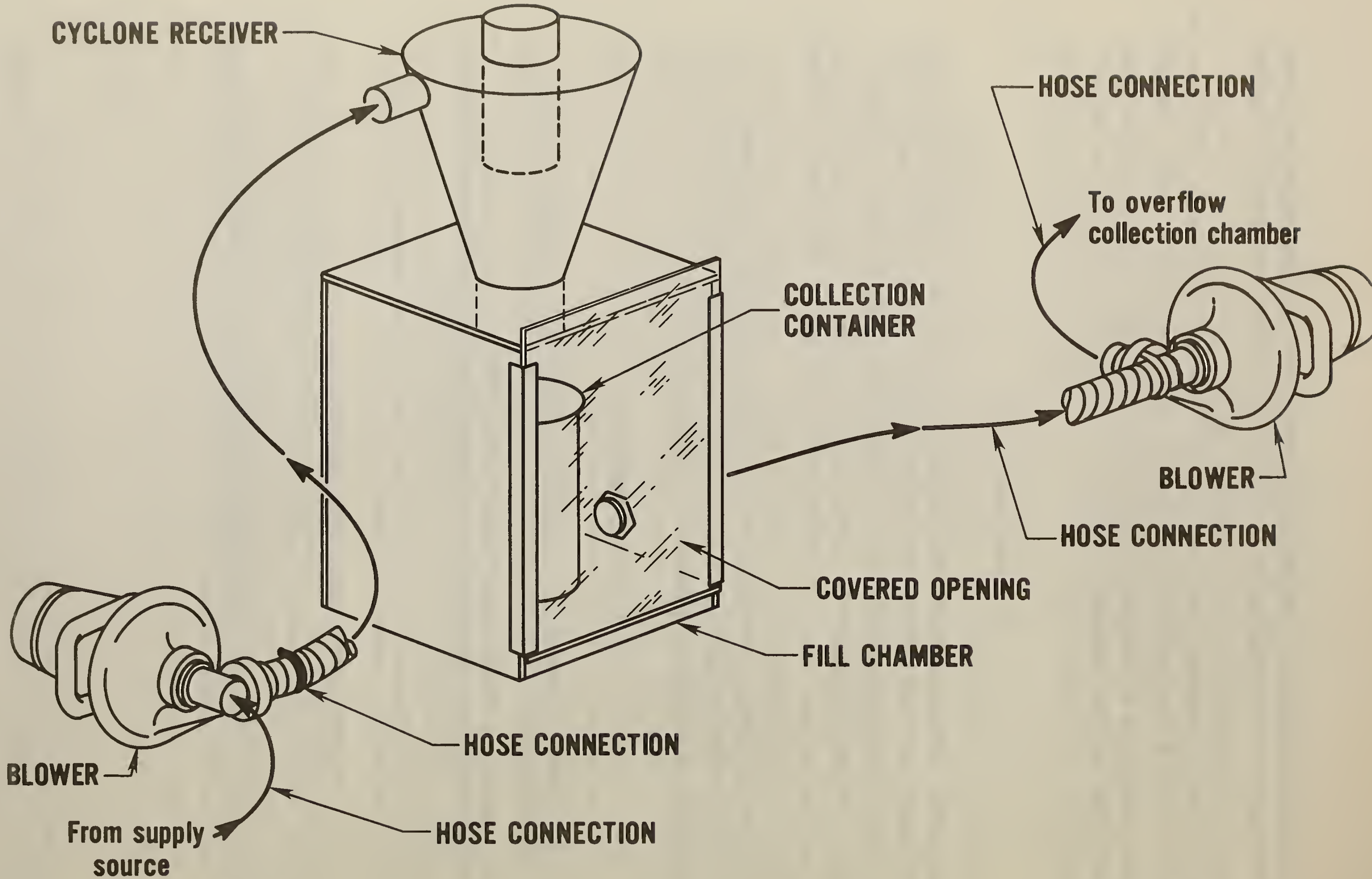

Figure 1. Insulation blowing apparatus

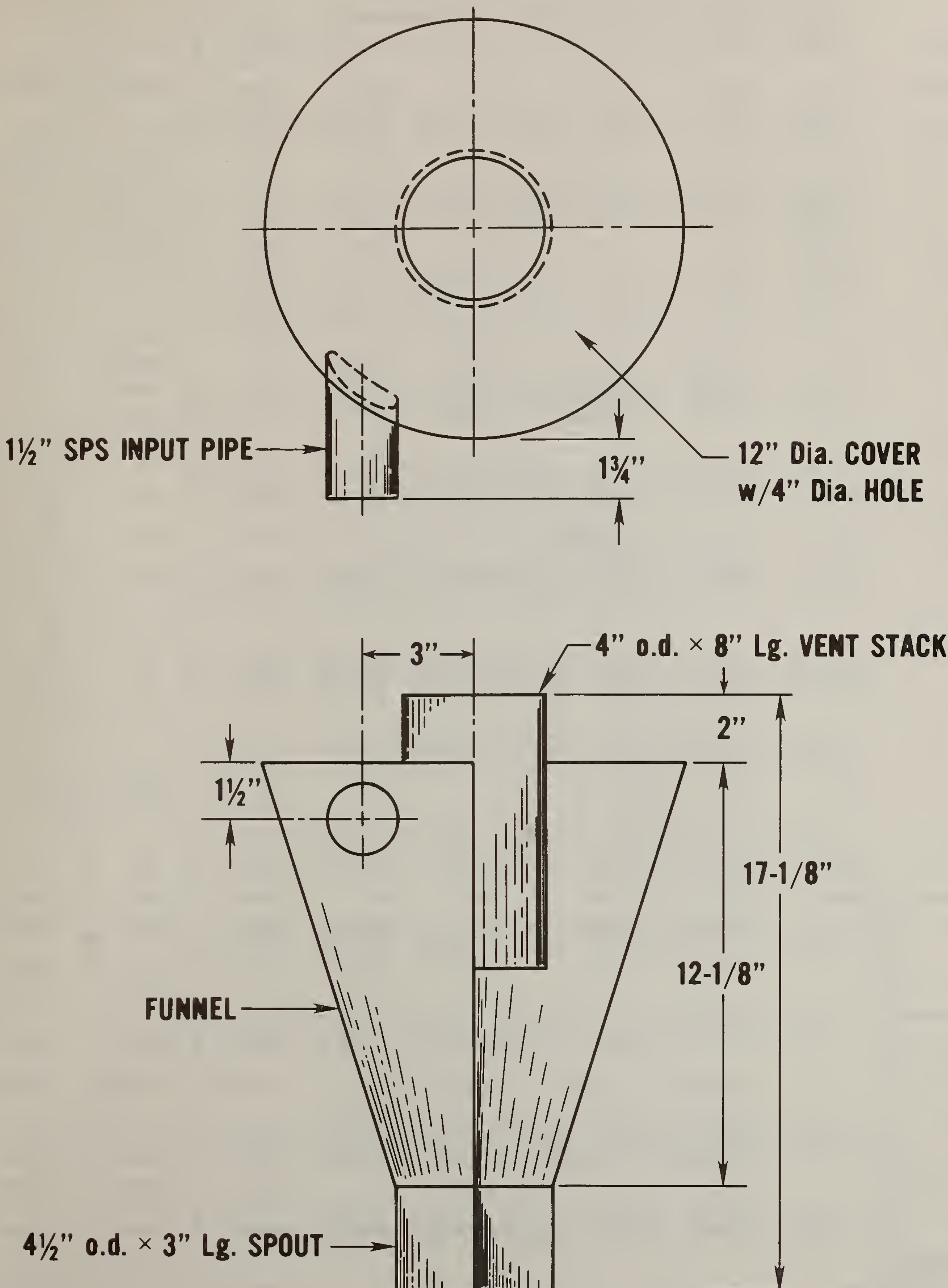

Figure 2. Cyclone receiver

Table 1. Settled density apparatus characteristics

Characteristics	Standard	LABORATORY 1	2	3	4	5	6	7
Specimen Container Material	glass	glass	glass	glass	glass	plastic*	glass	glass
Sides Straight/Flared	straight	F*	S	S	S	S	S	S
Inside Dia. (in)	5.9	6.2*	5.5*	~6.1*	5.5*	5.98	5.7*	5.6*
Height (in)	variable	10	11-3/4	~8-1/2	12	9.2	11-7/8	12
Volume (liters)	3.5 to 5	4	4.1	4	4.9	4.2	5.0	4.9
Disc Dia. (in)	variable	6	5-1/2	5-3/4	5-3/8	5.96	5-1/2	5-1/2
Disc weight (g)	75±5	81.1*	75.0	76.1	75.3	75.2	75	75.0
Fill Chamber Construction	N/A	wood	wood	wood	wood	wood	wood	wood
Height (in)	18	22-1/4*	24*	16-3/8*	18-1/4*	18	16-1/4*	17*
Width (in)	15	14-1/4*	14-1/2*	14-1/4*	15	15	13-1/2*	13*
Depth (in)	15	14*	14-1/2*	14-1/4*	15	15	14-1/2*	12*
Hose Dia. (in)	2	2	2	2	2	2	2	2
Supply hose length (in)	108±2	113*	117*	120*	100*	109	111*	107
Cyclone hose length (in)	72±2	62*	74-1/2*	72	74	81*	68*	73
Exit hose length (in)	36±2	106*	36	72*	36	114.5*	38	36
Blower Operating Volts								
Supply	40	115 *	40	~40	40	40	40	40
Overflow	40	115 *	40	~40	40	40	40	40
Operating Amps								
Supply	12	9*	--	5*	--	12	7.5*	11*
Overflow	12	11*	--	5*	--	12	7.5*	11*
Conditioning								
Temperature °F	69±9	75	73	--	70	70	70	70
Relative Humidity	50±5%	50%	50%	60%*	50%	50-52%	50%	50%
Shaker Type	N/A	RX-24	RX-24	RX-24	RX-24	RX-24	RX-24	RX-24
Shaker Displacement (in)	15/32	15/32	15/32	14/32*	14/32*	15/32	15/32	15/32
Cyclone dimensions								
Top diameter (in)	12	12	12	12	12.4*	12	11.8*	12.3*
Vent stack dia. O.D. (in)	4	3-7/8 I.D.	3-7/8 I.D.	3-7/8 I.D.	4 O.D.	3-7/8 I.D.	3-7/8 I.D.	3-7/8 I.D.
Total Vent stack length (in)	8	12*	8	8	8	--	8	8
Spout dia. OD (in)	4-1/2	4-9/32 I.D.	4-3/8 I.D.	4-3/8 I.D.	4-1/2 O.D.	4-5/16 I.D.	4-3/8 I.D.	4-5/8 I.D.
Spout length (in)	3	3	3	~3-1/4*	3	2-1/2*	2-7/8*	2-3/4*
Total Cyclone height (in)	17-1/8	17-1/4*	17*	17-1/4*	17-1/8	19-1/4*	18-7/8*	16-3/4*
Distance specimen container top to cyclone spout (in)	N/A	2	2	2-3/4	2	2-11/25	2	2

* Asterisks identify conditions or apparatus dimensions that do not meet standard requirements as given in the March 8, 1979, proposed standard.

Table 2. Settled density test results

	MATERIAL													
	K		L		M		N		O†		P†		Q	
Laboratory	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3
1	57.7	3.6	56.1	3.5	65.7	4.1	48.1	3.0	33.6	2.1	43.2	2.7	56.1	3.5
	54.5	3.4	56.1	3.5	67.3	4.2	51.3	3.2	36.8	2.3	41.6	2.6	59.3	3.7
	57.7	3.6	57.7	3.6	64.1	4.0	52.9	3.3	35.2	2.2	46.5	2.9	57.7	3.6
	54.5	3.4	54.5	3.4	67.3	4.2	49.7	3.1	36.8	2.3	43.2	2.7	54.5	3.4
2	46.6	2.91	45.5	2.84	59.9	3.74	43.6	2.72	30.0	1.87	38.6	2.41	54.6	3.41
	44.7	2.79	44.5	2.78	59.3	3.70	41.2	2.57	29.8	1.86	39.1	2.44	53.7	3.35
	44.7	2.79	45.3	2.83	58.8	3.67	41.6	2.60	30.0	1.87	39.1	2.44	54.1	3.38
	46.6	2.91	45.3	2.83	58.6	3.66	43.2	2.70	30.6	1.91	41.2	2.57	53.0	3.31
3	48.9	3.05	51.4	3.29	68.2	4.26	56.5	3.53	30.5	1.90	49.5*	3.09	60.1	3.75
	49.4	3.08	54.1	3.38	69.3	4.32	55.9	3.49	32.4	2.02	40.2*	2.52	56.8	3.55
	49.7	3.10	53.0	3.31	68.2	4.26	55.8	3.48	31.2	1.95	47.9*	2.99	57.3	3.57
	52.0	3.25	51.0	3.19	64.1	4.00	56.9	3.55	32.3	2.02	42.9*	2.68	56.2	3.51
4	48.4	3.02	48.5	3.03	58.3	3.64	47.4	2.96	31.6	1.97	41.0	2.56	55.1	3.44
	46.5	2.9	48.7	3.04	59.7	3.73	46.1	2.88	29.5	1.84	42.4	2.65	53.2	3.32
	46.5	2.9	49.8	3.11	61.0	3.81	44.7	2.79	29.5	1.84	41.5	2.59	52.7	3.29
	47.4	2.96	50.0	3.12	61.0	3.79	44.9	2.80	29.8	1.86	44.2	2.76	54.3	3.39
5	49.5	3.09	61.2	3.82	52.1	3.25	45.6	2.85	35.1	2.19	39.9	2.49	55.7	3.48
	50.9	3.18	61.4	3.83	51.1	3.19	46.1	2.88	36.2	2.26	41.6	2.60	55.3	3.45
	50.8	3.17	61.4	3.83	51.1	3.19	46.4	2.90	36.4	2.27	39.1	2.44	54.1	3.38
	51.9	3.24	61.2	3.82	51.1	3.13	46.8	2.92	34.0	2.12	40.4	2.52	54.6	3.41
6	53.7	3.35	49.5	3.09	61.2	3.82	52.2	3.26	36.8	2.30	45.1	2.81	57.3	3.57
	54.4	3.39	52.2	3.26	67.3	4.20	54.0	3.37	34.9	2.18	47.0	2.93	63.2	3.95
	54.8	3.42	53.3	3.33	64.2	4.01	54.2	3.38	35.8	2.24	49.9	3.11	57.5	3.59
	59.3	3.70	54.8	3.42	66.1	4.12	52.5	3.28	34.0	2.12	50.3	3.14	58.8	3.67
7	54.3	3.39	52.2	3.26	66.9	4.18	47.3	2.95	35.7	2.23	39.8	2.49	57.1	3.56
	54.0	3.37	52.5	3.28	66.6	4.16	47.5	2.96	34.9	2.18	39.1	2.44	56.4	3.52
	54.5	3.40	51.5	3.21	66.6	4.16	49.9	3.11	35.7	2.23	40.4	2.52	54.0	3.37
	52.7	3.29	53.1	3.31	66.7	4.17	48.7	3.04	35.2	2.19	39.9	2.49	55.1	3.44

* Sample clogged blower. Operated with stoppages.

† Material O was cotton and P was ground wood.

Table 3. Settled density test cell averages ordered from lowest to highest density (kg/m^3)

Laboratory	O †	P †	N	K	L	Q	M
	Material						
1	35.60	43.62	50.50	56.10	56.10	56.90	66.10
2	30.10	39.50	42.40	45.65	45.15	53.85	59.15
3	31.60	*	56.28	50.00	52.38	57.60	67.45
4	30.10	42.28	45.78	47.20	49.25	53.82	60.00
5	35.42	40.25	46.23	50.78	61.30	54.92	51.35
6	35.38	48.08	53.22	55.55	52.45	59.20	64.70
7	35.38	39.80	48.35	53.88	52.32	55.65	66.70
Column Avg.	33.37	42.25	48.97	51.31	52.71	55.99	62.21

* Sample clogged blower causing stoppages. Data not used in analysis.

† Material O was cotton and P was ground wood.

Table 4. Average blown density compared with average settled density

Material	Average Blown Density (kg/m^3)*	Average Settled Density (kg/m^3)*	Percent Difference **
O	24.08	33.00	27
P †	22.85	41.98	46
N	33.46	48.71	31
K	39.90	50.51	21
L	38.71	52.14	26
Q	40.42	55.84	28
M	38.56	61.56	37

* Average values shown for O, N, K, L, Q and M were calculated using data submitted from laboratories 2 through 7.

** The percent difference was based on settled density.

† Average values for P were calculated using data submitted by laboratories 2, 4, 5, 6, and 7.

NOTE: Material O was cotton and P was ground paper.

Table 5. Settled density test cell standard deviations ordered from lowest to highest density (kg/m^3)

Laboratory	Material O †	P †	N	K	L	Q	M
1	1.53	2.06	2.07	1.85	1.31	2.07	1.53
2	0.35	1.16	1.18	1.10	0.44	0.68	0.58
3	0.91	*	0.52	1.37	1.44	1.73	2.29
4	1.01	1.41	1.25	0.91	0.76	1.08	1.29
5	1.11	1.05	0.51	0.98	0.12	0.71	0.50
6	1.20	2.47	1.02	2.54	2.24	2.75	2.66
7	0.39	0.54	1.20	0.81	0.67	1.38	0.14
Pooled Standard Deviation	1.01	1.58	1.21	1.48	1.20	1.64	1.56

* Sample clogged blower causing stoppages. Data not used in calculating pooled standard deviations.

† Material O was cotton and P was ground wood.

Table 6. Precision estimates for the cyclone settled density test

Material	Overall Average kg/m^3	Repeatability Standard Deviation kg/m^3	Repeatability Coefficient of Variation %	Reproducibility Standard Deviation kg/m^3	Reproducibility Coefficient of Variation %
O †	33.37	1.01	3.03	2.78	8.33
P †	42.25	1.58	3.74	3.54	8.39
N	48.97	1.21	2.47	4.86	9.92
K	51.31	1.48	2.88	4.25	8.28
L	52.71	1.20	2.28	5.18	9.83
Q	55.99	1.64	2.93	2.46	4.40
M	62.21	1.56	2.51	5.95	9.56

† Material O was cotton and P was ground wood.

Appendix A. Revised settled density test procedure as published in the July 6, 1979 Federal Register

§ 1209.4 Test procedures for determining settled density.

The settled density of lose fill insulation must be determined before the corrosiveness test (1209.5) and the smoldering combustion test (1209.7) can be performed. This section describes the procedure for determining the settled density of loose fill insulation.

(a) *Apporatus ond moterials:*

(1) An insulation specimen container with a flat bottom and an inside diameter of 15.0±1 cm, straight sides [without a flared lip or spout, (Apparatus #1)]. The height of the beaker shall be such that the distance between the bottom of the cyclone and the top edge of the beaker is 8.5 cm±1.0 cm. (3.39 in±.39 in).

(2) A flat-rigid disc with a total weight of 75±5 g (2.65±0.18 oz) and of a suitable diameter to fit loosely into the specimen container. Weight may be added to the center of the disc to bring the total weight to the required 75±5 g (Apparatus #2).

(3) A balance of 2 kg (4.4 lbs) capacity accurate at least to 0.2 g (0.007 oz) (Apparatus #3).

(4) Blower apparatus, two units (supply and overflow) meeting the following specifications: (The Commission staff has found that a Breuer Electric Manufacturing Co., Model 98805 blower is suitable for this purpose, although other blowers may be suitable.) (Apparatus #4).

(i) Each blower apparatus shall be capable of blowing an average of 272.2 kg (600 lbs.) of insulation per hour.

(ii) Each blower apparatus shall have a nominal air flow of 2.1 cm^3/min. (75 ft^3/min.)

(iii) Each blower apparatus shall have a nominal motor speed of 16,450 revolutions per minute at 115 VAC.

(5) A shaker unit capable of shaking 4.5 kg (10 lb) of weight with a vertical motion of 0.5 g Root Mean Square (RMS) acceleration at an approximate frequency of 9 Hertz (Hz) and displacement of approximately 1.17 cm ($^{15}/_{32}$± $^{1}/_{32}$ in.) ±.08 cm peak to peak. (The Commission staff has found that a Tyler Industries, Portable Sieve Shaker Model Rx-24 is suitable for this purpose, although other shakers may be suitable.) (Apparatus #5).

(6) Fill chamber with inside dimensions of 45.7 cm (18 in) high × 38.1 cm (15 in) wide × 38.1 cm (15 in) deep, with covered openings that will allow a radiant panel tray to be slid through the chamber, (see Figure 1 for details) (Apparatus #6).

(7) A cyclone receiver (see Figure 2 for complete details). (Apparatus #7).

(8) Various lengths of nominally 2-inch diameter hose (see Figure 1 for details), as follows:

(i) A supply source hose, 274.3±5.1 cm (9 ft±2 in) (Apparatus #8(i)).

(ii) A cyclone receiver hose, 182.9±5.1 cm (6 ft±2 in) (Apparatus #8(ii)).

(iii) A fill chamber exit hose, 91,.4±5.1 cm (3 ft±2 in) (Apparatus #8(iii)).

(iv) An overflow exhaust hose, length as needed (Apparatus #8(iv)).

(9) Blower Control(s) capable of operating the two blowers at 40 volts RMS. As an example, a variac for each of the two blowers with sufficient rating to operate at 40 volts and 12 amperes RMS would be acceptable (Apparatus #9).

(10) An insulation holding container to hold a sufficient quantity of insulation to fill the specimen container four times.

(11) A garden rake, 50.8 cm (20 in) wide (Apparatus #11).

(12) A shovel (Apparatus #12).

(b) *Conditioning:* Specimens shall be conditioned to equilibrium at 21±5° C (69.8±9° F) and 50±5 % relative humidity. A less than 1% change in net weight of the specimen in two consecutive weighings with two hours between each weighing constitutes equilibrium.

(c) *Test specimen preporotion:*

(1) *Insulotion intended for pneumotic opplicotions.* If the insulation is intended for pneumatic applications, the test specimens shall be prepared in the following manner:

(i) If ambient laboratory conditions are different from the conditioning requirements specified in (b) above, begin testing the specimen for settled density within 10 minutes after it has been removed from the conditioned area.

(ii) Pour the conditioned insulation into the holding box (Apparatus #10) in sufficient quantity to fill the specimen container (Apparatus #1 shown in Figure 1) four times. Manually break up any large clumps of material that might cause feeding problems.

(2) *Insulotion intended for pouring opplications:* If the insulation is intended for pouring applications, the test specimens shall be prepared in the following manner:

(i) If ambient laboratory conditions are different from the conditioning requirements specified in (b) above, begin testing 10 minutes after it has been removed from the conditioned area.

(ii) Pour loose fill insulation into a simulated attic space until full. The attic space shall be formed by two nominal 2 x 6 (243 cm) (8 ft) long joists placed 40.6 cm (16 in) on center with 1.27 cm (½ in) plywood nailed to the ends and bottom. Fluff the material with a garden rake (Apparatus #11), applyilng a series of small amplitude strokes while moving the rake slowly along the joist. Repeat the fluffing process six times.

(d) *Procedures:*

(1) *Procedures for insulation intended for pneumotic opplicotions.* If the insulation is intended for pneumatic applications, conduct the following procedures:

(1) The test shall be conducted in an area conditioned to the requirements of § 1209.4(b).

(ii) The apparatus shall be set up as shown in Figure 1. (Apparatus #9 and #10 are not shown in Figure 1, but are described at § 1209.4(a)). Connect one end of the supply source hose (Apparatus #8.i) to the intake of the supply blower (Apparatus #4). The other end will be used to pick up insulation from the holding container (Apparatus #10). Connect one end of the cyclone receiver hose (Apparatus #8.ii) to the outlet of the supply blower and the other end to the cyclone receiver (Apparatus #7). Connect one end of the fill chamber exit hose (Apparatus #8.iii) to the intake of the overflow blower (Apparatus #4) and the other end to the fill chamber (Apparatus #6). The fill chamber shall be placed on a flat and level surface. Connect one end of the variable length overflow exhaust hose (Apparatus #8.iv) to the outlet of the overflow blower. The other end should be conveniently placed to reduce insulation dust in the test area.

(iii) Weigh the empty insulation specimen container and record its weight.

(iv) Place the empty insulation specimen container in the fill chamber (Apparatus #6) centered under the cyclone reciever (Apparatus #7), and close the front cover.

(v) Adjust the blower control(s) (Apparatus #9) such that the supply and overflow blowers will operate at a no load voltage of 40 volts RMS.

(vi) Turn on the blowers simultaneously and proceed to fill the insulation specimen container by picking up material from the holding container using the supply source hose.

(vii) The container may fill unevenly, i.e. a void may tend to form off center in the container. If this occurs, stop the blowing process and rotate the container 180 degrees and continue the blowing process until the container just begins to overflow. If, for any reason, the filling process is interrupted for more than one minute or for more than the one time allowed to rotate the container, begin the process again.

(viii) Gently screed the excess material using a straight edge so as to leave a uniform surface of the insulation flush with the top of the container.

(ix) Weigh the filled and leveled container and record the weight. Take care not to bump or jar the container so as not to introduce any extraneous settling of the insulation.

(x) Cover the container to prevent spilling and secure the container to the shaker. Operate the shaker for a period of 5 minutes±15 seconds.

(xi) Remove the container from the shaker and uncover, taking care not to bump or jar it. Lower the disc (Apparatus #2) very slowly into the container until it starts to contact the insulation. At this point, release the disc and allow it to settle onto the insulation under its own weight.

(xii) Measure the volume of the space occupied by the settled insulation using the bottom edge of the disc as the upper datum point. If the disc is not level, measure the high and low points of the bottom of the disc and average the readings and use this as the height measurement in calculating the volume (V_s). This settled insulation volume and insulation weight (w) shall be used to calculate the settled density.

(xiii) Repeat this procedure [steps (i through xi)] using another specimen of the insulation until four settled densities are obtained for a given material. Then average these figures to arrive at a final settled density.

(2) *Procedures for insulation intended for pouring applications.* If the insulation is intended for pouring applications, conduct the following procedures:

(i) Weigh the empty insulation specimen container and record its weight.

(ii) Using a shovel (Apparatus #12) remove insulation from the simulated attic space and place it into the specimen container until the container just begins to overflow.

(iii) Follow steps (vi) through (xii) as specified under *Procedures for insulation intended for pneumatic applications.*

(iv) Repeat this procedure (steps (i) through (iii)) using another specimen of the insulation until four settled densities are obtained for a given material. Then average these figures to arrive at a final settled density.

(e) *Insulation intended for pouring and pneumatic applications.* If the insulation is intended for both pouring and pneumatic applications, or if it is uncertain whether the insulation will be poured or installed pneumatically, the insulation shall be tested for settled density using the test specimen preparation and test procedures at § 1209.4 (c) and (d) for each of the applications. The larger of the two settled density values shall be used in performing the corrosiveness test at § 1209.5 and the smoldering combustion test at § 1209.7.

(f) *Calculations:*

Calculate the settled density of each specimen using the following formula:

Settled Density in $kg/m^3 = W/V_s$, where

W = combined weight of the container and insulation in grams, minus the weight of the container in grams.

V_s = volume of insulation in liters after shaking.

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15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The cyclone settled density test for cellulosic loose fill insulation was evaluated in an interlaboratory test program. Seven laboratories tested seven cellulosic loose fill insulations manufactured for the home insulation market. The participating laboratories were surveyed to evaluate the test apparatus and test methodology used at each location. It was concluded that none of the apparatus used in the program completely met the prescribed dimensional requirements for the test. However, statistical analysis of the test results showed that the repeatability coefficient of variation ranged from 2.3 to 3.7 percent with a median of 2.9 percent, and the reproducibility coefficient of variation ranged from 4.4 to 9.9 percent with a median of 8.4 percent. The median difference in density for the materials was 28 percent when blown density was compared to settled density. This study indicated that there is reasonable assurance that test results on the same material obtained at one laboratory can be reproduced in one of the other laboratories.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Cellulosic thermal insulation; cyclone settled density test; precision estimates.

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