NBSIR 81-2200

Evaluation of Alternate Mounting Methods for the Evaluation of Brattice Cloth on ASTM E-162

Emil Braun and Ramon Reyes-Virella

Center for Fire Research
National Engineering Laboratory
U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

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Final Report

Prepared for:

U.S. Bureau of Mines
Pittsburgh, Pennsylvania 15213

and

Safety and Health Administration
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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EVALUATION OF ALTERNATE MOUNTING METHODS FOR THE EVALUATION OF BRATTICE CLOTH ON ASTM E-162

Emil Braun and Ramon Reyes-Virella

Abstract

Twenty-two brattice cloth samples representing a cross section of materials available to the coal mining industry were tested using ASTM E-162, Surface Flammability of Materials Using a Radiant Heat Energy Source. The tests were conducted to evaluate alternative mounting methods that would improve test repeatability. Five mounting methods were studied. The study showed that the flame spread index was dependent on the mounting method. The foil/spacer/backing method produced the highest values, while the backing only method produced the lowest values. However, measurement dispersion was unaffected by mounting method.

Key words: ASTM E-162; brattice cloth; coal mining; fire test; flame spread; sample mounting; ventilation cloth.

1. INTRODUCTION

At the request of the Mine Safety and Health Administration (MSHA) and the Bureau of Mines (BOM), the Center for Fire Research (CFR) at the National Bureau of Standards (NBS) initiated a review of current practices for the certification and approval of ventilation control materials for use in underground coal mines.

This report is a first step in the overall review process. It considers the impact on mean values and dispersion of the data about the mean for several mounting methods, using ASTM E-162, Surface Flammability of Materials Using a Radiant Heat Energy Source, as the basic procedure. However, additional work will have to be conducted to determine the relative importance of the acceptance criterion in terms of life safety. Large-scale tests will be necessary to verify that geometric changes do not adversely impact on the acceptance criterion. Furthermore, it is possible that if an adequate large-scale program is conducted, attention may be directed to test methods other than ASTM E-162.

The current basis of measurement and acceptance of ventilation control materials may warrant changes in the acceptance criterion used with ASTM E-162.

2. BACKGROUND

According to title 30, section 75.302 of the Code of Federal Regulations, the area around the working face of a coal mining operation must be adequately ventilated to remove flammable, explosive and noxious gases, dusts, and fumes. This is generally accomplished by the installation of line brattice (i.e., ventilation cloth) from the last open crosscut of a working section to control the direction of airflow. Line brattice is a cloth like material that extends from the roof of a mine to its floor dividing a passageway into an incoming flow and an outgoing flow of air. Line brattice is also used to temporarily close off unused passageways to minimize the size of the ventilation system necessary to maintain minimum acceptable flows in the working areas. Check curtains to minimize air leaks between various sections of a mine are also made from line brattice.

Line brattice is used extensively in mining applications other than ventilation control (e.g., shield equipment during welding, transporting, or storage). The general use of line brattice could represent a significant fire hazard. Ignition and rapid flame propagation along installed brattice could reduce the likelihood of successful escapes for those miners inby[1] of the fire origin. The Code of Federal Regulations, therefore, requires that "brattice cloth and ventilation tubing being used underground shall be flame resistant to the extent that the flame spread index shall be 25 or less...The flame spread index shall be determined by ASTM methods of test E-84 or E-162" [1][2].

Although the regulations allow use of either E-84 or E-162, the primary test administered by MSHA and generally employed by the industry is ASTM E-162. This test method was originally designed to test traditional building materials. With the introduction of synthetic materials, modifications were introduced into the test procedure to accommodate the different material behavior exhibited by them. Currently, MSHA's Certification and Approval Center follow ASTM E-162 practices for synthetic materials. Test samples are mounted on an asbestos-cement board with a wire screen covering. Measurements are made for 15 minutes or until all flaming has extinguished, whichever is longer.

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[1] This indicates the direction towards the working face of the mine.

[2] Numbers in brackets refer to the references at the end of this report.

In 1972, Murphy [2] conducted comparative tests of line brattice material in large-scale tests and in ASTM E-162. He found that those samples that propagated a flame 15 feet or more had flame spread indices greater than 100, while those samples that propagated a flame less than 10 feet had a flame spread index no greater than 20. This appears to support the establishment of 25 as the maximum allowable flame spread index. However, the mounting method described by Murphy for the ASTM E-162 test differs from that currently used by MSHA. Murphy used 6.5 mm standoffs between the brattice cloth and the asbestos-cement board and no screen cover.

This work represents the only large-scale tests conducted to substantiate the use of ASTM E-162 and the flame spread acceptance criterion of 25 or less.

3. TEST MATERIALS

Two sets of brattice cloth were used in the evaluation of the effects of mounting method on flame spread index. One set, table 1, was obtained directly from several manufacturers, while the other set, table 2, was obtained from MSHA. Together they represent a reasonable cross section of available materials for use in ventilation control in underground mining.

Table 1 contains several sets of materials that differ either in color or scrim pattern. Samples 1a, 1b, and 1c differ only in scrim design. Samples 5a and 5b are a clear plastic differing in scrim design, while 5y has the same scrim design as 5a but is dyed yellow.

The materials in table 2 were selected by MSHA and sent to NBS for testing on the ASTM E-162. Among the samples received were several weights of flame-retardant treated jute as well as one untreated jute brattice cloth.

Along with the weight of each cloth is a description of the major chemical components used.

4. TEST PROCEDURE

The apparatus and test procedures for the ASTM E-162 are described in detail in the Annual Book of ASTM Standards, part 14. The apparatus consists of a radiant panel made from a high porosity refractory material (30 cm wide by 46 cm high). The panel is mounted vertically and a premixed air-gas mixture is burned in contact with the refractory surface. The energy output of the

Table 1. Description of NBS brattice cloth

Sample Number	Weight		Construction
	oz/yd^2	kg/m^2	
1	14	0.47	PVC[a] (yellow) Film - Nylon Scrim
2	4	0.13	Aluminum & PVC Laminate - Polyester Scrim
3	16	0.55	PVC (yellow) Film - Nylon Scrim
4	43	1.44	PVC (white) Film - Nylon Scrim
5a	14	0.48	PVC (clear) Film - Polyester Scrim
5b	14	0.48	PVC (clear) Film - Polyester Scrim
5y	13	0.45	PVC (yellow) Film - Polyester Scrim
6	12	0.40	PVC (clear) Film - Polyester Scrim
6y	12	0.39	PVC (yellow) Film - Polyester Scrim
7	40	1.36	PVC (clear) Film - Polyester Scrim
8	38	1.29	PVC (clear) Film - Polyester Scrim
9	13	0.43	PVC (yellow) Film - Polyester Scrim
10	17	0.59	PVC (yellow) Film - Polyester Scrim
11	10	0.32	Jute, FR[b] Treated
12	13	0.43	Jute & PVC Laminate
13	35	1.18	PVC (white) Film - Polyester Scrim

[a] Polyvinyl Chloride
[b] Fire Retardant

Table 2. Description of MSHA brattice cloth

Sample Number	Weight		Construction
	oz/yd^2	kg/m^2	
14	15	0.51	Jute, FR[a] Treated
15	20	0.68	Jute, FR Treated
16	24	0.81	Jute, FR Treated
17	10	0.32	Cotton, FR Treated
18	20	0.68	Jute & PVC[b] Laminate
19	15	0.51	PVC Film
20	13	0.43	PVC (yellow) Film - Polypropylene Scrim
21	12	0.40	PVC (clear) Film - Polypropylene Scrim
22	14	0.47	Jute, Untreated

[a] Fire Retardant

[b] Polyvinyl Chloride

panel, as measured by a radiation pyrometer, is equivalent to a blackbody temperature of 670°C. A stack is placed above the test specimen and receives hot combustion gases. Four equal length thermocouples, wired in parallel, are installed in the stack to measure the average temperature of the exhaust gases. The flame spread index, I_s, is computed as the product of the flame spread factor, F_s, and the heat evolution, Q:

$$I_S = F_S \times Q$$

Q is corrected for each backing assembly.

The standard test specifies that a 15 cm by 46 cm specimen backed by an asbestos-cement millboard be placed in front of and inclined towards the panel. In this study a 25 mm mesh screen was placed over all specimens and five different backing schemes were investigated. They were:

- Aluminum foil and board;
- Spaces (6.5 mm), aluminum foil, and board;
- Board only;
- Spaces (6.5 mm) and board;
- No backing material.

The board used was a calcium silicate board with a nominal density of 738 Kg/m^3.

The standard test procedure requires that a correction factor for the holder assembly (i.e., metal frame and backing) be applied to the test data. Each of the five backing methods were blank tested and a temperature-time curve was plotted, figures 1-5. These figures were used to determine appropriate correction factors for the heat release data, Q.

5. TEST RESULTS AND DISCUSSION

The analysis of the data was divided into: (1) a consideration of the effects that different mounting methods have on the average I_s values, and (2) on changes in the dispersion of the data about the mean as a function of mounting method. The first determines which samples are acceptable according to the acceptance criterion $I_s \leq 25$. The second defines the precision that can be attached to the mean values, I_s.

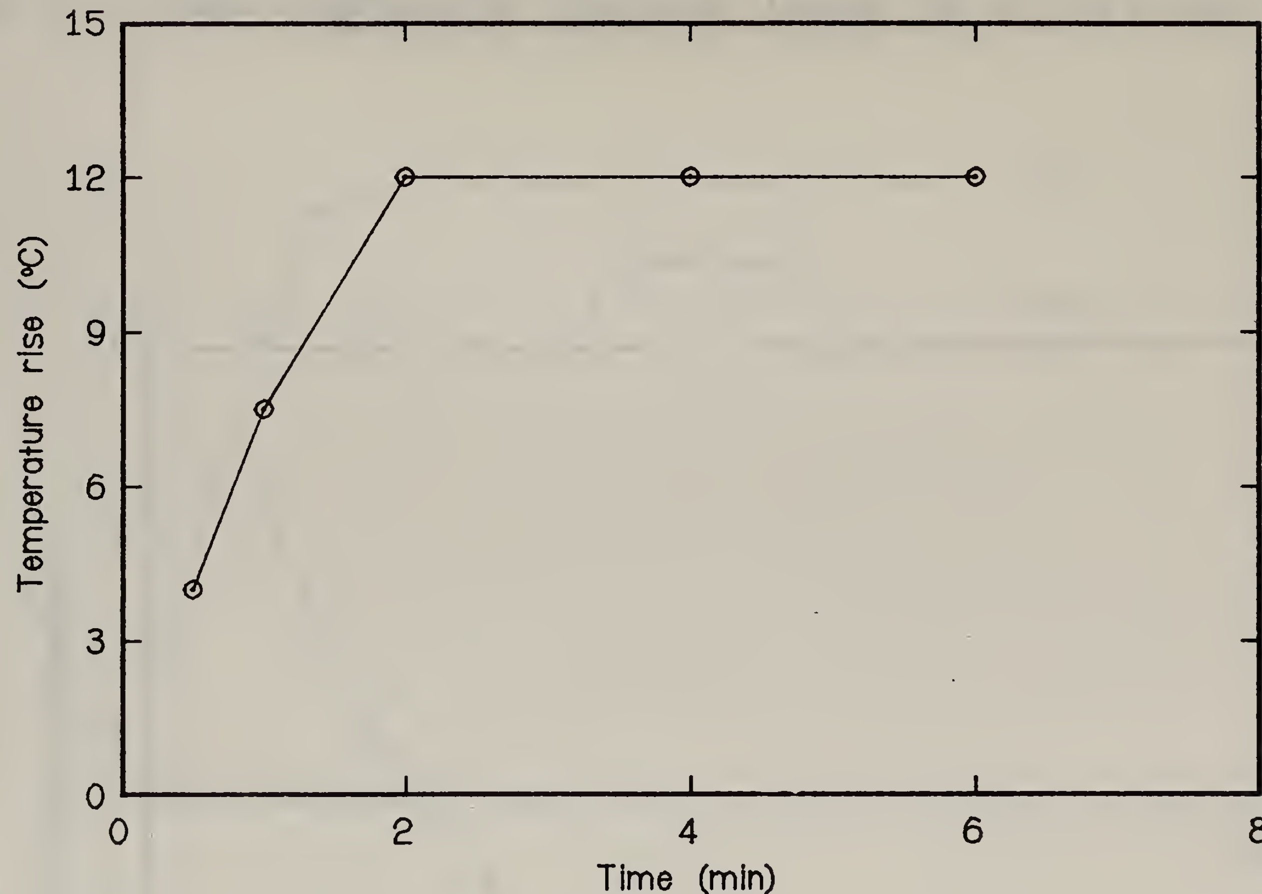

Figure 1 – Stack temperature correction factor for ASTM E-162 using a holder assembly of calcium silicate board

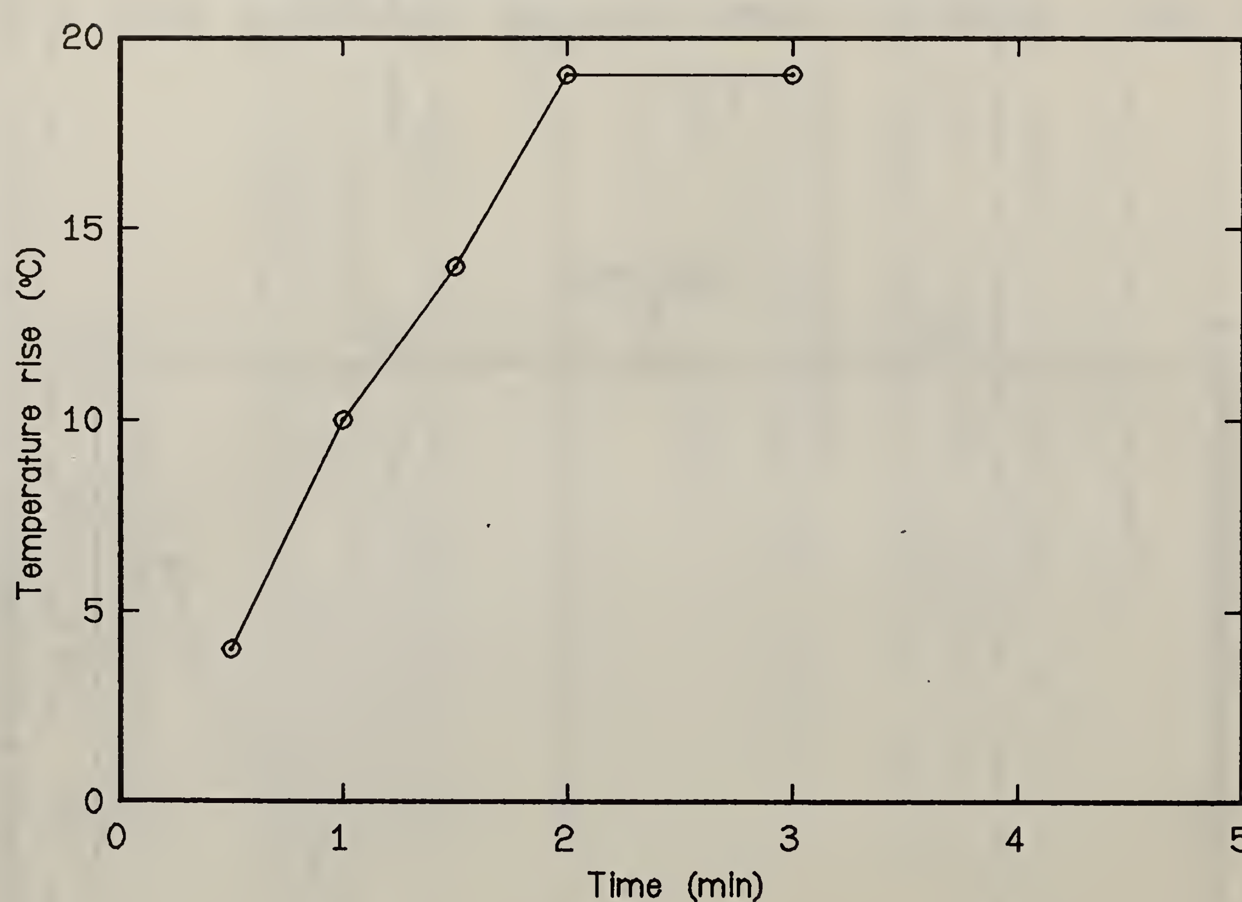

Figure 2 – Stack temperature correction factor for ASTM E-162 using a holder assembly of a screen and calcium silicate board

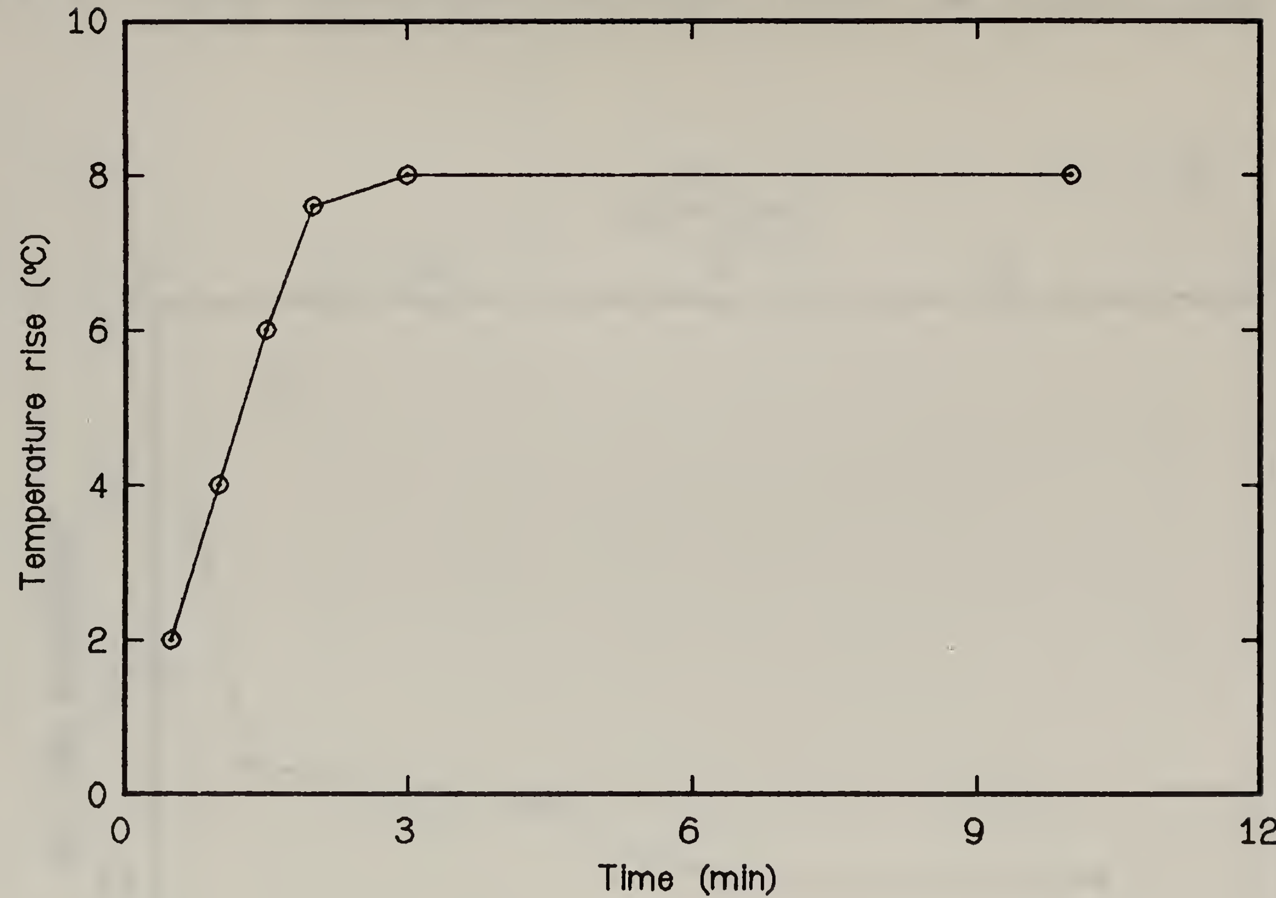

Figure 3 – Stack temperature correction factor for ASTM E-162 using a holder assembly of foil and calcium silicate board

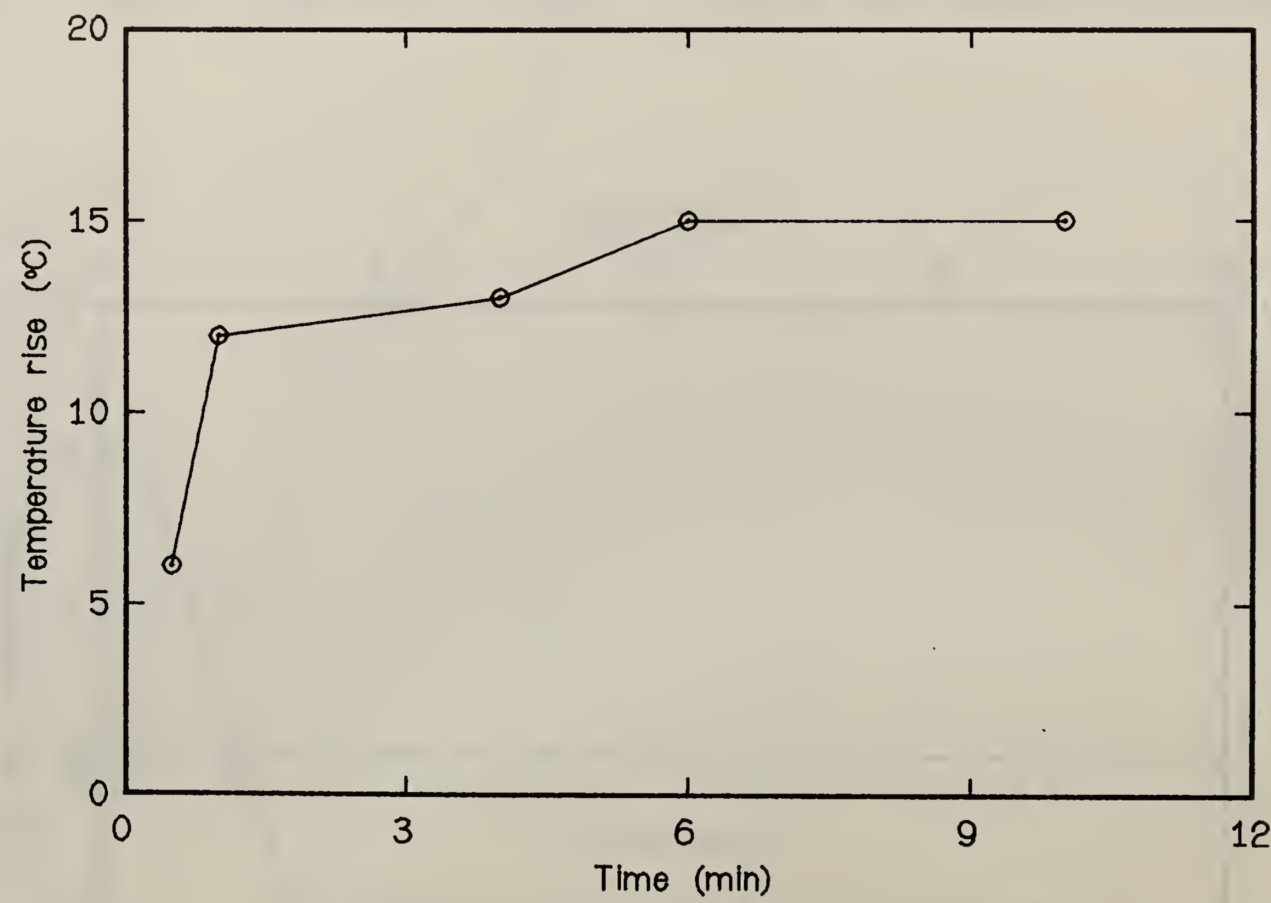

Figure 4. – Stack temperature correction factor for ASTM E-162 using a holder assembly of a screen, spacer, foil, and calcium silicate board

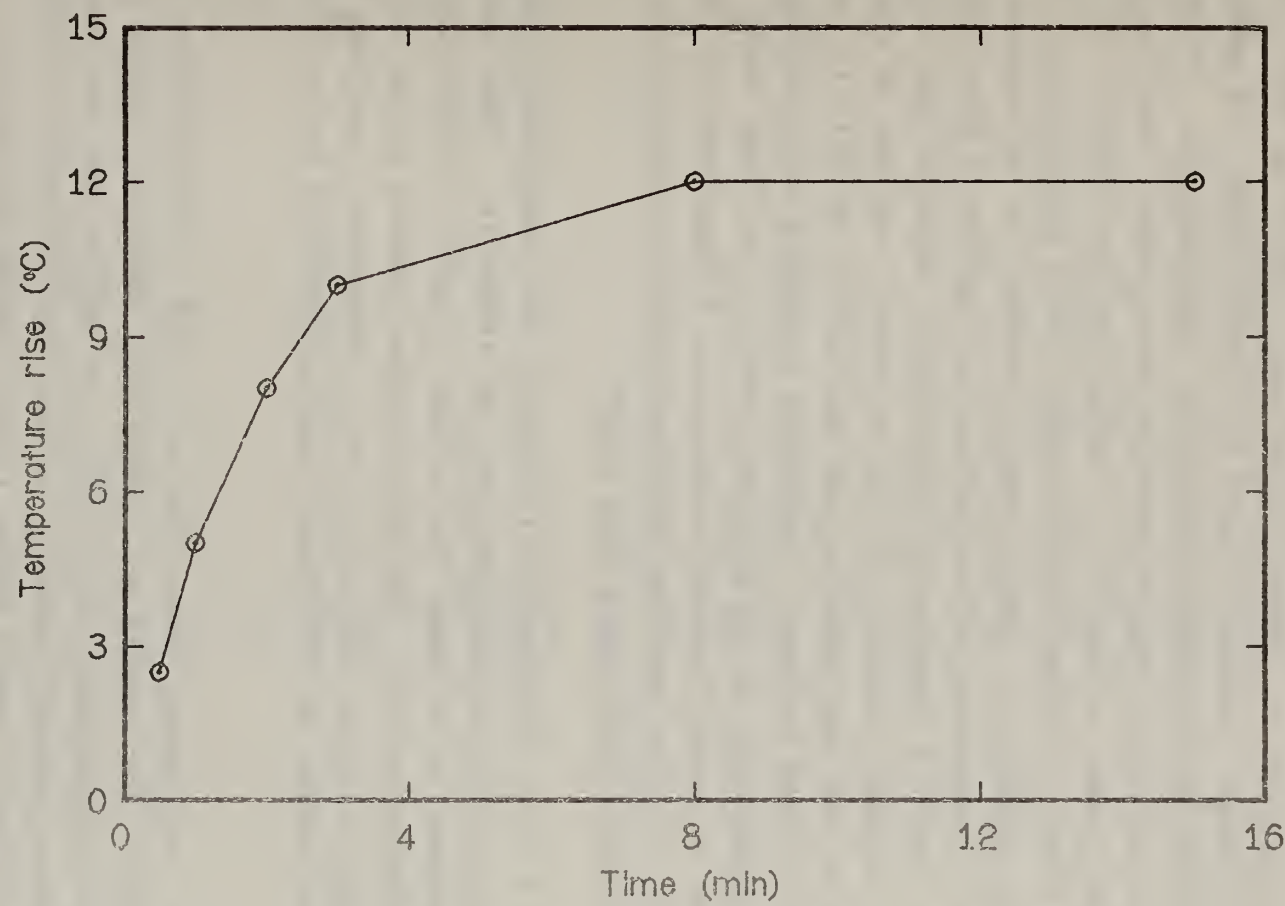

Figure 5 – Stack temperature correction factor for ASTM E-162 using a holder assembly of wire screen

Since two sets of samples were investigated with variations in the mounting method, each set will be analyzed separately.

5.1 Comparing Average Values

Table 3, summarizes the results of tests using four different mounting methods and the first 13 materials. The largest range of average values for the various mounting methods was obtained with sample #11 (7 to 470). For this sample, the foil/board combination gave the lowest value. In general, however, the use of foil gave higher results than those mounting methods without the foil. Those tests that had the material make contact with the board tended to produce the lowest values of I_s. Except for two samples (2V, 6), the board only had lower I_s values than the spacer board combination. The presence of the foil appeared to enhance energy feedback to the sample. This was probably due to a combination of reflection and conduction along the foil-material interface. While a fraction of the incident radiation was absorbed by the sample, the remainder reached the foil surface. Portions of this energy were reflected back to the test material and absorbed by the foil to be conducted to the foil's cooler regions. The energy spreading more rapidly in the foil elevated the temperature of the specimen ahead of the flame front. It is not clear which mode of energy transfer predominates because the foil/board combination has higher values than the foil/spacer/board combination in only 9 of the 17 samples where comparative data exists.

Sample number 2 is an aluminum-vinyl laminate that demonstrates the necessity for testing both surfaces when they are dissimilar. When the aluminum surface was exposed to the panel the average I_s value was very low, less than 3, for all mounting methods. The vinyl surface exposed to the radiant panel had values that were much higher but still acceptable, less than 25, for all mounting methods except the foil/board combination which had an I_s equal to 27.

Sample number 1 represents three lots, a, b, and c, from the same brattice cloth design. The results were reasonably consistent except for sample 1aS using the spacer/board combination. In all but one case the rough finished surface produced higher I_s values than the smooth finished surfaces. Both surfaces of sample number 10 were tested and here also the results agreed qualitatively with sample number 1 results.

Several samples were received dyed (yellow) and undyed (clear) (5a and 5y: 6 and 6y). The dyed materials appear to give lower I_s values in tests that did not use the foil. When the foil was used the results appear independent of coloring.

Table 3. Average flame spread index for NBS brattice cloth using different backing assemblies

Sample Number	Foil/Board	Foil/Spacer/Board	Spacer/Board	Board
laS	-	181	13	2
laR	-	233	34	7
lbS	276	196	85	14
lbR	283	240	109	31
lcS	107	182	90	-
lcR	149	253	47	1
2A	2	1	3	3
2V	27	17	8	15
3	89	-	-	16
4	172	-	-	17
5a	188	188	34	2
5b	134	225	25	1
5y	196	208	1	1
6	119	232	2	107
6y	252	27	1	1
7	288	118	-	31
8	99	209	25	3
9	72	102	77	1
10S	230	158	37	1
10R	-	194	54	1
11	7	470	223	39
12	310	-	-	2
13	120	75	14	6

Table 4, summarizes the results of tests on the last nine materials. As with the previous set of materials, this set also had the smallest I_s values with the board only mounting method. Four samples (numbers 17, 18B, 20R, and 20S) are higher I_s values with no backing as compared to the foil/spacer/board combination. Sample number 18, a jute and PVC laminate, again demonstrates the importance of testing both surfaces when they are different.

In the preceding paragraphs, several qualitative statements were made concerning average response as a function of the mounting method. Due to uncertainties in the average I_s values, a question can be raised concerning the significance of some of the differences. For a given level of significance, Natrella [3] outlines a procedure for comparing the averages of several products. The products in this case are the various mounting methods. In order to perform the analysis the estimate of the variance (square of the standard deviation), S^2 is necessary. The calculated standard deviations for each average I_s value is tabulated in tables 5a and 5b. Using the values obtained from a table of t- distribution for a 95% significance level, a significance range for each material is calculated. If the absolute difference between any two sample averages exceeds this calculated range, the averages then differ significantly from each other.

Table 6 lists those samples whose range of average I_s values were found to exceed the calculated significance range. The empirical and significance ranges are included in the table for each sample. Of the 35 sets of data listed in tables 3 and 4, 13 had sample variabilities such that the range of average I_s values for the various mounting methods were not indicative of sample mounting method interactions.

5.2 Comparing Performance Variability

In addition to selecting a method for the evaluation of ventilation control materials that correlates with acceptable and nonacceptable field experience, attention must be given to the uncertainty associated with any measurement process. It is, therefore, necessary to determine if any mounting method yields a significantly smaller dispersion of measured values about an average I_s than the other tested methods.

Since the board only mounting method is currently employed by MSHA for certification and approval, it will be used as the reference for evaluating the variability of the other mounting methods. Because the magnitude of the variance may be related to the magnitude of the average I_s value, only those

Table 4. Average flame spread index for MSHA brattice cloth using different backing assemblies

Sample Number	Foil/Spacer/Board	No Backing	Board
14	513	320	377
15	684	407	158
16	463	343	290
17	3	19	3
18B	8	404	262
18W	310	166	81
19	97	48	6
20R	3	15	1
20S	1	8	1
21S	205	53	7
21R	431	153	11
22	1183	703	331

Table 5a. Standard deviation for the average flame spread index for NBS brattice cloth using different backing assemblies

Sample Number	Foil/Board	Foil/Spacer/Board	Spacer/Board	Board
1aS	-	13.02	4.18	1.31
1aR	-	53.18	10.43	4.61
1bS	7.18	23.58	8.42	18.04
1bR	73.79	42.84	21.64	34.81
1cS	52.02	24.94	4.87	-
1cR	66.32	18.51	37.71	0.32
2A	0.47	0.16	1.00	1.61
2V	25.21	8.55	24.31	1.19
3	46.48	-	-	13.30
4	82.10	-	-	7.66
5a	75.56	39.15	2.92	0.22
5b	36.97	66.72	7.88	0.76
5y	130.64	74.56	0.46	1.11
6	13.41	90.60	0.70	24.02
6y	29.12	18.42	0.46	0.22
7	306.58	26.89	-	29.76
8	42.58	63.38	14.78	5.44
9	11.44	46.44	15.10	0.64
10S	227.71	15.23	12.06	0.32
10R	-	26.26	13.97	0.05
11	1.58	57.62	43.80	42.76
12	550.20	-	-	0.63
13	40.12	25.84	4.11	3.13

Table 5b. Standard deviation for the average flame spread index for MSHA brattice cloth using different backing assemblies

Sample Number	Foil/Spacer/Board	No Backing	Board
14	75.8	95.1	151.0
15	202.6	86.3	55.1
16	191.1	89.9	92.6
17	0.5	19.4	0.3
18B	0.8	107.4	113.5
18W	223.1	41.9	39.7
19	24.9	11.7	2.7
20R	5.4	11.5	0.6
20S	0.3	4.0	0.5
21S	45.5	4.1	5.1
21R	54.9	3.4	19.1
22	125.5	179.1	169.1

Table 6. List of materials that showed significant (.95) differences due to mounting method

Sample Number	Range of Values	Range of Significance
1aS	179	16
1aR	226	62
1bS	262	33
1bR	252	99
1cS	92	66
1cR	252	82
5a	238	109
5b	224	80
5y	207	158
6	230	99
6y	251	36
8	206	82
9	101	53
11	463	88
13	69	50
15	526	259
18B	395	178
19	91	32
20S	8	5
21S	198	52
21R	421	66
22	853	315

samples found to be unaffected by mounting method will be used for evaluation of the dispersion of the data due to each mounting method.

In the preceding section, 13 samples were found to be unaffected by mounting method (i.e., those not listed in table 6). The ratio of the variance of each mounting method to the variance of the board only method was computed for each sample from the data in tables 5a and 5b. These values were compared to the appropriate value taken from a table of F-distributions for a 95% level of significance. Table 7a shows the results of this comparison for the NBS brattice cloth, while table 7b is the MSHA brattice cloth results. A plus (+) in the tables indicates that specific mounting method had less variability than the board only. A minus (-) indicates that the board only tests were variable. No compelling case can be made for favoring any one method over another from either set of data.

While the statistical data do not appear to indicate a superior mounting method, end-use conditions can be used to dictate the best mounting method for the E-162. Brattice cloth used for ventilation control is free-hanging and rarely makes contact with a heat sink. Under most conditions, each brattice cloth surface is exposed to air flowing counter to the airflow on its opposite surface. When used to close off unused portions of a mine, airflow is along one surface with near stationary air on its other surface. This appears to favor either the no-backing method or the spacer/board method for mounting samples in the E-162. In general, the spacer/board method and the no-backing method were found to produce higher flame spread indices than the board only method. Materials appear to be available that can pass either mounting method. Other end-uses for brattice cloth would result in a heatsink being placed in contact with one surface. The presence of the heat sink should reduce the fire hazard just as the flame spread index was lowest for the board only tests.

6. CONCLUSION

The mean value of the flame spread index, I_s, was found to depend on the mounting method. The foil/spacer/backing mounting method produced the highest I_s value, while the backing only mounting method produced the lowest I_s.

Changes in the mounting method did not appreciably affect measurement dispersion.

Table 7a. The variability of material performance for various backing assemblies in comparison to the board only (NBS brattice cloth)

Sample Number	Foil/Board	Foil/Spacer/Board	Spacer/Board
2A	+[a]	+	+
2V	+	+	+
3	-[b]		
4	-		
7	-	+	
10S	-	-	-
10R		-	-
12	-		

[a] Indicates that specified system had less variability than board only.

[b] Indicates that specified system had more variability than board only.

Table 7b. The variability of material performance for various backing assemblies in comparison to the board only (MSHA brattice cloth)

Sample Number	Foil/Spacer/Board	No Backing
14	+[a]	+
16	+	+
17	+	-
18W	-[b]	+
20R	-	-

---

[a] Indicates that specified system had less variability than board only.

[b] Indicates that specified system had more variability than board only.

Based on end-use considerations, the spacer/board and no-backing mounting methods appear to be the preferred mounting methods. Because of large-scale tests conducted by BOM, the spacer/board mounting method should be selected.

7. RECOMMENDATIONS

Additional large-scale tests are necessary to define the appropriateness of this test method or any other test method used for brattice cloth. These large-scale tests should furnish information over a broader range of conditions. The data should determine the effects of mine height and width as well as ventilation rate on brattice cloth fire performance.

8. REFERENCES

[1] Code of Federal Regulations, title 30, section 75.302-3.

[2] Murphy, E. M., Flame spread evaluation of ventilation cloth, Report of Investigations 7625, Bur. Mines (U.S.), 1972.

[3] Natrella, M. G., Experimental statistics, NBS Handbook 91, Nat. Bur. Stand. (U.S.), 1966.

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Emil Braun and Ramon Reyes-Virella

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Triadelphia, West Virginia 26059

10. SUPPLEMENTARY NOTES

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

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

Twenty-two brattice cloth samples representing a cross-section of materials available to the coal mining industry were tested using ASTM E-162, Surface Flammability of Materials Using a Radiant Heat Energy Source. The tests were conducted to evaluate alternative mounting methods that would improve test repeatability. Five mounting methods were studied. The study showed that the flame spread index was dependent on the mounting methods. The foil/spacer/backing method produced the highest values, while the backing only method produced the lowest values. However, measurement dispersion was unaffected by mounting method.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

ASTM E-162; brattice cloth; coal mining; fire test; flame spread; sample mounting; ventilation cloth.

13. AVAILABILITY

[XX] Unlimited
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