NEW TEST FOR EVALUATING THE FLAME RESISTANCE OF CONVEYOR BELT

by

HARRY C. VERAKIS

U.S. Department of Labor
Mine Safety and Health Administration
Approval and Certification Center
Triadelphia, West Virginia

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INTRODUCTION

A conveyor belt fire presents a serious safety hazard in an underground coal mine, To combat the conveyor belt fire hazard, the 1969 Federal Coal Mine Health and Safety Act specified that on and after March 30, 1970, all conveyor belting acquired for use in underground coal mines shall be flame resistant. The federal mine safety regulation promulgated to implement the mandate of the "1969 Act" specifies that conveyor belts which have been approved under Title 30 Part 18, Section 18.65 (formerly Schedule 2G) as flame resistant meet the statutory provision of the "1969 Act". This stipulation currently appears in Title 30, Part 75, Section 75.1108-1, of the Code of Federal Regulations. The "2G" small-scale flame test accomplished its original purpose of removing very flammable natural rubber and other nonfire-resistant conveyor belts from underground coal mines. However, the more recent coal mine fire history of conveyor belts and test data from large-scale fire tests on conveyor belts indicates the need for an improved approval test to further reduce the fire hazard of conveyor belts used in underground coal mines.

A review of underground coal mine fires involving conveyor belts which occurred within the past two decades was made by the MSHA. During the 19-year period of 1970-88, there were 39 fires involving conveyor belting reported to MSHA. Table 1, derived from MSHA's "Belt Entry Ventilation Review: Report of Findings and Recommendations, 1989", lists the number of fires from 1970-88 which involved conveyor belting. Review of the data indicates that about 75 percent of these fires occurred in mainline belt entries. Over the last 6 years of this period, the number of fires involving conveyor belting increased. Some of these fires resulted in burning as much as 610 m of conveyor belting and caused injuries and a fatality. The fatality occurred to a miner who suffered a heart attack during firefighting activities, Eleven miners were treated for smoke inhalation in four separate belt fire incidents. Several mines were sealed or shut down for an extended period of time as a result of conveyor belt fires. For instance, the Marianna Mine in western Pennsylvania has been sealed since March 1988, due to a conveyor belt fire.

TABLE I*

FIRES INVOLVING CONVEYOR BELTS

PERIOD	NUMBER OF FIRES	SUM TOTAL
1970	2	2
1971-73	1	3
1974-76	3	6
1977-79	5	11
1980-82	7	18
1983-85	11	29
1986-88	10	39

* As an update to Table 1, there were 9 fires involving conveyor belts from 1989 through mid 1992 for a sum total of 48.

BELT FLAMMABILITY PROGRAM

A program toward improving conveyor belt fire -safety was undertaken by MSHA. The program encompassed a study to evaluate the flammability hazard of mine conveyor belting. The work was performed in conjunction with the Bureau of Mines, U. S. Department of the Interior (BOM). Several objectives of the program were to: (a) conduct large-scale fire tests on conveyor belts at different airflows, (b) develop new laboratory-scale MSHA approval test for evaluating the flame resistance of conveyor belts, and (c) revise MSHA approval and use regulations to incorporate a new laboratory-scale test for flame-resistant conveyor belts.

Large-scale Belt Fire Tests

The large-scale conveyor belt tests were conducted in a surface fire gallery constructed and operated by the BOM. The surface gallery consists of a concrete floor and a block wall tunnel with an arched metal roof. The tunnel walls and roof are insulated. The dimensions of the fire tunnel are 3.8 m wide, about 27 m long and 2.5 m high from the floor to the center of the arched roof. The cross-sectional area of the tunnel is 7.5 sq m. Ventilation is provided by an axial vane fan connected to one end of the tunnel.

Large-scale tests were conducted on synthetic rubber (SBR), neoprene, and polyvinyl chloride (PVC) conveyor belts which met MSHA, British Coal, or Canadian requirements for flame resistance. Most tests were made using a single strand of conveyor belt, 1.1 m wide and 9.1 m long. Two tests were made using run-of-the-mine coal placed on the belting. Several tests were made using a top and bottom strand of belt. The conveyor belt for testing was placed on a conventional belt-carrying structure located inside the fire tunnel. The ignition source consisted of a mixture of 5.7 liters of kerosene and 1.9 liters of gasoline placed in a metal tray located under the leading edge of the belt test sample. The ignition source typically burned for 5 to 7 minutes.

Fire tests were made at airflows from 0 to 6.1 m/s. However, the majority of the tests were made at airflows of 1.5 and 4.1 m/s. Flame propagation rates of the belts tested were obtained by analyzing data from thermocouples embedded in the top surface along the length of the belt sample.

Table 2 shows flame spread data from large-scale testing for several types of belts over a range of airflows and for two tests with coal on the conveyor belt.

Assessment of Tests

There were four types of flammability behavior characterized from the large-scale conveyor belt fire tests:

1. No flame propagation and burning only in the area of the ignition zone,

2. Slow flame propagation (less than 1.5 m/min) with consumption of the belt sample,

3. Rapid flame propagation termed "flashover" (greater than 1.5 m/min) over the top surface of the belt with little or no flame damage on the bottom surface of the belt, and

4. Rapid flame propagation termed "flashover" (greater than 1.5 m/min) with continued burning and destruction of the belt.

The large-scale test results show the flammability characteristics of conveyor belts are significantly affected by airflow and the composition of a belt. The highest flame spread rates occurred when the airflow was 1.5 m/s. As noted in Table 2, more fuel was added to the ignition source to obtain flame propagation of an SBR belt at an airflow of 4.1 and 6.1 m/s. "Flashover" occurred at an airflow of 1.5 m/s for several types of SBR and PVC belts. Smoke and other combustion products spread against airflows of 0.4, 0.8 and 1.5 m/s. Some PVC and neoprene belts did not propagate flame over the full range of airflows used in the tests. Further information on the large-scale belt fire studies is presented in several other publications (Lazzara and Perzak, 1987) and (Verakis and Dalzell, 1988).

<u>Double Strand Belt Tests</u>

A limited number of large-scale fire tests were made at airflows of 1.5 and 4.1 m/s, using two strands of SBR or PVC conveyor belting. The top belt sample was 9.1 m long and the bottom belt was 4.6 m long. Both top and bottom belts were 1.1 m wide. The belt samples were placed on the conveyor structure with the top belt spaced about 0.4 m above the bottom belt. In the ignition area, the vertical spacing between the belts was about 0.2 m . The metal tray used to contain the fuel for ignition was centered under the leading edges of the top and bottom belts. As in the single strand tests, the ignition source consisted of 7.6 liters of liquid fuel.

The data from the double strand tests also shows that an airflow of 1.5 m/s produced the highest flame-spread rate. Flame propagation and combustion damage in the double strand belt tests were greater at an airflow of 1.5 m/s than at an airflow of 4.1 m/s.

Tests with Coal

Two tests were also made using double strands of rubber (SBR) conveyor belting loaded with run-of-mine bituminous coal on the top belt. These tests were conducted at airflows of 1.5 and 4.1 m/s. The top belt was 10.7 m long and the bottom belt was 6.1 m long. The width of the belt was 1.1 m. The amount of coal loaded on the belting was about 53.6 kg/m. The coal loading was 0.2 m in height along the centerline of the belt and about 0.5 m in width. In these two tests, the fire propagated along the belts with coal and portions of belting falling from the rollers to the floor and continuing to burn. The flame spread rate was about three times higher at the lower airflow than at the higher airflow (Table 2). Significant rollback of smoke and combustion products occurred at the airflow of 1.5 m/s, but not at the airflow of 4.1 m/s.

TABLE 2

Airflow effect on belt flame spread rate for large-scale tests

Belt Type	Airflow (m/set)	Flame spread rate (m/min)	
SBR, 4 ply, MSHA	0.8	0.24	
Same	1.5	0.92	(1)
Same	2.6	0.34	
Same	4.1	0.37	
SBR, 3 ply, MSHA	0	0.21	
Same	0.4	0.34	(2)
Same	0.8	3.0	(3)
Same	1.5	5.5	
Same	2.6	0.40	
Same	4.1	0.61	(5)
Same	6.1	0.67	(6)
SBR, double strand, coal on top strand	1.5	1.8 *	
Same	4.1	0.6 *	
Neoprene, 1 ply, MSHA	1.5	0.0	
Same	4.1	0.0	
PVC, MSHA	0.8	0.0	
Same	1.5	---	(4)
Same	2.6	0.0	
Same	4.1	0.0	
PVC, NCB	0.8	0.0	
Same	1.5	0.0	
Same	2.6	0.0	
Same	4.1	0.0	

(1) Flashover (rate of 5.8 m/ min)
(2) Flashover (rate of 5.5 m/ min)
(3) Flashover (rate of 6.1 m/ min)
(4) Flashover (rate of 13.7 m/ min)
(5) 3.8 liters of extra fuel added to ignition source
(6) 7.6 liters of extra fuel added to ignition source
* top belt

<u>Laboratory-Scale Belt Approval Test</u>

One objective of MSHA's belt flammability program was to develop a new laboratory-scale approval test for determining the flame resistance of conveyor belts. In conjunction with the MSHA Approval and Certification Center (A&CC), the BOM conducted studies to develop a laboratory-scale test apparatus and test procedure for evaluating the flammability of conveyor belts. Test results and technical data obtained from the large-scale belt tests were used and factors such as scaling of the test, airflow conditions and type of ignition source were evaluated in developing a laboratory-scale test.

A pass/fail criterion was established for the large-scale test relative to the amount of burn damage to a belt. The criterion was based on tests conducted at an airflow of 1.5 m/s, since the highest flame spread rates and greatest amount of damage from flame spread occurred at this airflow. A belt would pass the large-scale test if damage by the fire was less than the 9.1 m long test sample and an undamaged portion remained across the width of the sample. A laboratory-scale fire tunnel for belt testing was subsequently developed using the pass/fail criterion and test results from the large-scale test as a basis (Lazzara and Perzak, 1989).

The new laboratory-scale apparatus is about 1.8 m long by 0.46 m square. The test specimen used is 0.23 m wide by 1.5 m long which is about one-fifth the size of the belt sample used in the large-scale tests. Other features of the test apparatus are a removable steel rack to hold the belt sample in the tunnel and a moveable impinged jet burner for the ignition source. Natural gas or methane is used as the fuel for the burner. A schematic of the laboratory-scale belt test apparatus is shown in Figure 1. For a test in this apparatus, an airflow of 1 m/s is used and the belt sample is subjected across its width to the jet burner for 5 minutes, Detailed features of the new belt evaluation laboratory test (BELT) and the flame test procedures have been prepared by the BOM for the MSHA, A&CC (Fire Test Procedures BOM, MSHA, 1989).

Tests on samples of the same formulations of belts used in the large-scale fire studies were made in the laboratory-scale test. The test conditions in the laboratory test were established to correspond with belt fire damage results obtained from the large-scale fire tests. The test criterion established for the laboratory-scale test is that a belt passes if in three separate trials a portion of the 1.5 m length sample remains undamaged across its width (BOM, MSHA, 1989). Test trials in the laboratory-scale test were made using nine different synthetic rubber and eight PVC conveyor belts.

Overall, the test results from the laboratory-scale test were in good agreement with the large-scale belt fire test results. Complete agreement on a pass/fail basis was obtained for the nine synthetic rubber belts. Agreement on a pass/fail basis was obtained for six of the eight PVC belts. For the two remaining PVC belts, one passed the large-scale test and failed the laboratory-scale test; and one failed the large-scale test and passed the laboratory-scale test (Lazzara and Perzak, 1989).

MSHA EVALUATION PROGRAM

MSHA held a public meeting in January 1989, to discuss its program plans for conveyor belt flammability testing and approval (Minutes of Public Meeting MSHA, A&CC, 1989). The large-scale belt fire tests, development of the laboratory-scale test and MSHA's intent to replace its belt approval test (2G) with the new laboratory-scale test through rulemaking procedures were discussed. Subsequent to the public meeting, an interim testing program was established by the A&CC to further evaluate the new laboratory-scale test. The interim testing program has been ongoing at the A&CC test facility. This program has permitted conveyor belt manufacturers to: (1) obtain tests on different belt formulations and, (2) assess the flammability performance of their belt constructions.

Currently, 21 companies have participated in the interim testing program and almost 700 individual flammability tests of conveyor belt samples have been made. There were 112 different types (construction and formulation) of belts that passed the test criterion of the new laboratory-scale test. The belts were categorized into four classes and the results of different types within the class that passed the test criterion were tabulated. A general summary of the data is shown in Table 3. The class designated as "composites" generally consisted of neoprene and SBR combinations or neoprene and butadiene rubber. The data in Table 3 are not intended to represent all types of belt formulations and constructions, since some of the belts evaluated were experimental designs. The belt flammability data obtained by each participating company has assisted in the development of improved flame-resistant belting which passes the laboratory-scale test.

TABLE 3

Summary of Test Data of Interim Program

Class of Belt	Number of Types that Passed
SBR	0
Neoprene	49
PVC	34
Composites	29

Rulemaking Action

Through rulemaking, MSHA intends to revise its present "2G" test for acceptance of flame-resistant conveyor belt to the new laboratory-scale test. This revision would, in MSHA's view, provide for improved flame-resistant conveyor belting for the mining industry and enhanced safety for miners. Following successful rulemaking, the new laboratory-scale test would replace the existing "2G" test.

Proposed Rule

MSHA announced its proposed rule for testing and approval of flame-resistant conveyor belts in the Federal Register on December 24, 1992. The proposed revisions would also modify MSHA's safety standard in Title 30, Code of Federal Regulations, Part 75.1108-1 to require the acquisition of conveyor belts meeting the new test. Public comments were received during the comment period for the proposed rule. The comments will be considered by MSHA as part of the rulemaking process.

SUMMARY

Large-scale belt fire tests were conducted on different types of conveyor belts at airflows ranging from 0 to 6.1 m/s. The test results show the highest flame spread rates were obtained when the airflow was 1.5 m/s. Data from the large-scale tests were used and test scaling factors and features were assessed in developing a new laboratory-scale test for evaluating the flame resistance of conveyor belting. The test criterion established for the laboratory-scale test is based on the extent of fire damage to the belt sample.

The MSHA, A&CC has established an interim testing program for manufacturers to obtain flammability data on the performance of their different types of conveyor belting when evaluated in the laboratory-scale test. Nearly 700 individual flame tests of conveyor belt samples were made. There were 112 different types of conveyor belts that passed the test criterion for the laboratory-scale test.

MSHA has published a proposed rule in the Federal Register for testing and approval of flame-resistant conveyor belts. As stated in this proposed rule, MSHA plans to revise its present conveyor belt acceptance test to the new laboratory-scale test. The new test would identify conveyor belts which are difficult to ignite and are self-extinguishing under the test conditions. It is designed to significantly decrease or eliminate the hazard of flame propagation along the belt and thus will reduce the potential for disaster,

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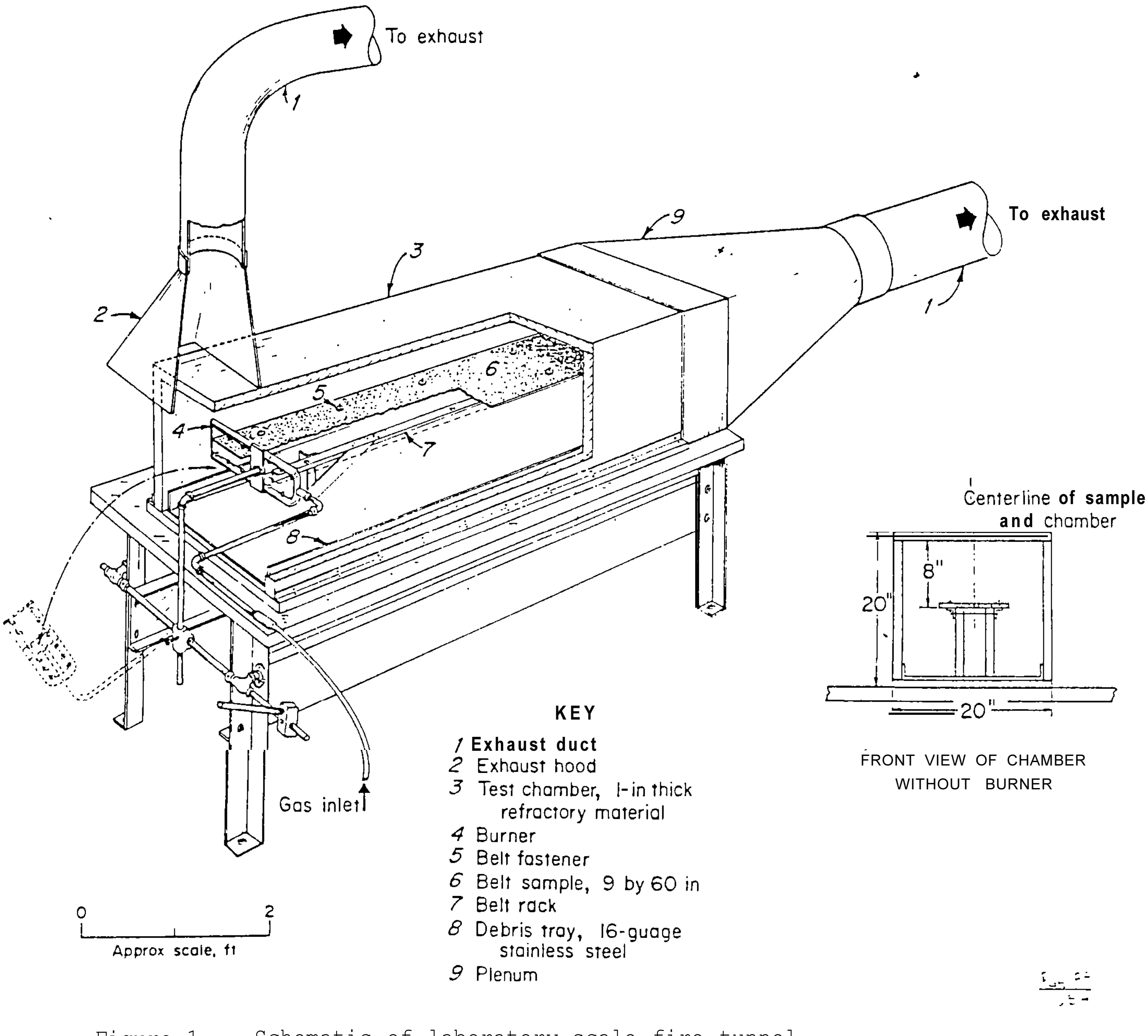

Figure 1. - Schematic of laboratory-scale fire tunnel. (courtesy, Bureau of Mines)