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FIRE HAZARD EVALUATION OF MINE CONVEYOR BELTS

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Studies were performed by the Bureau of Mines, U.S. Department of Interior, in cooperation with MSHA to evaluate the fire-resistant characteristics of conveyor belts in both large and small-scale tests. Different types of conveyor belts meeting MSHA, Canadian and British standards for fire resistance were tested at airflows from neutral to 4.1 m/sec. in large-scale tests using single and double strands of belting. Analysis of the fire test data shows the rate of airflow and type of conveyor belt have a significant effect on the flammability results for mine conveyor belts. Data from the large-scale tests were subsequently used by the Bureau of Mines to' develop a laboratory-scale test for MSHA's Approval and Certification Center to use in evaluating the fire resistance of nine conveyor belting. The use of the newly developed laboratory-scale test in MSHA's conveyor belt approval testing program is discussed.

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INTRODUCTION

A fire involving conveyor belting in an underground mine presents a serious safety hazard. To reduce this fire hazard, conveyor belting used in underground coal mines is required to be flame-resistant as prescribed by MSHA in Title 30, U.S. Code of Federal Regulations (30 CFR), Part 75, Section 75.1108(l). The present acceptance test used by MSHA to determine flame resistance of conveyor belts is specified in 30 CFR, Part 18, Section 18.65(2). The test is commonly referred to as the "2G Test", and is performed in a small cubical chamber. Details of the test were originally published in 1955 as Schedule 28(3). As part of a program to improve Federal mine safety standards in the USA, studies were initiated in 1985 by the Mine Safety and Health Administration (MSHA), Approval and Certification Center (A&CC) to evaluate the fire hazard of mine conveyor belting. The major objectives of the program were:

1. to determine the burning characteristics of conveyor belts subjected to a selected. range of airflows, particularly in large-scale tests;

2. to obtain and evaluate fire test data from large- and small-scale tests;

3. to develop an improved small-scale MSHA approval test for fire-resistant conveyor belts; and,

4. to revise MSHA approval requirements for fire-resistant conveyor belts which would incorporate an improved small-scale fire test.

The experimental studies were conducted by the Bureau of Mines in cooperation with the MSHA, Approval and Certification Center. A fire tunnel complex was constructed by the Bureau of Mines to perform large-scale tests. Data obtained from the large-scale tests were then used by the Bureau of Mines to develop a laboratory-scale test for determining the fire-resistant properties of conveyor belts.

LARGE SCALE FIRE STUDIES

A series of large-scale conveyor belt fire tests were conducted by the Bureau of Mines in cooperation with A&CC. The tests were made in a surface fire gallery built to simulate a mine entry. The surface gallery complex is an arched fire tunnel which consists of a concrete floor, concrete block walls and a metal roof. The tunnel roof and walls are insulated with ceramic blanket material. The length of the fire tunnel is about 27m. The floor of the fire tunnel is 3.8m wide and the height from the floor to the center of the arch roof is 2.5m. The cross-sectional area of the tunnel is 7.5 sq.m. The tunnel is connected to an axial vane fan by a 6m. long transition section.

Tests were made using conveyor belt specimens from non fire-resistant to fire-resistant types which met MSHA, British Coal (formerly NCB) and Canadian (CANMET) approval requirements. The conveyor belts used in the test program were made of synthetic rubber (SBR), chloroprene (neoprene); or polyvinyl chloride (PVC). Tests were typically made using a single strand of belting l.lm wide and 9.lm long. Several tests were made using double strands of belting and also with run-of-the-mine coal placed on the belting.

Belts for testing were placed on a conventional belt-carrying structure which was placed inside the fire tunnel. The distance of the belting for test was about 1.2m from the apex of the tunnel roof. A rectangular metal tray containing a mixture of 5.7 liters of kerosene and 1.9 liters of gasoline was used as the ignition source. The tray was located under the leading edge of the belt test specimen. The ignition area was shielded to reduce airflow effects on the ignition process.

A majority of the ‘fire tests were made at airflows of 1.5 and 4.2 m/set. However, some tests were also made using airflows of 0.8 and 2.6 m/set. Air was forced by the fan through the belt fire test area toward the exit of the fire tunnel. Flame spread rates for the belt fire tests were obtained by evaluating data from thermocouples embedded in the top surface of the belt specimen along its centerline and near each edge.
In preparation for a large-scale test, the conveyor belt specimen was cut and placed on the belt-carrying structure. Thermocouples were embedded in the belt specimen and connected to a data collection system. Airflow for a test was determined from anemometer readings made at several locations along and across the belt specimen. Adjustments to obtain a selected airflow were made prior to a test by changing the pitch of the fan blades and/or by regulating the air inlet to the fan with a circular metal disk. Two video cameras were also used to record the progress of the fire tests.

At the beginning of a test, the liquid fuel mixture used as the ignition source was introduced into the metal tray. The fuel was subsequently initiated by a match or small torch. The progress of the fire test was monitored and videotaped.

After completion of a test, the length of fire damage to the belt specimen was measured and its weight loss was also determined.

A more detailed description of the large-scale fire testing program is provided in papers by Lazzara and Perzak (4) and Verakis (5).

RESULTS OF LARGE-SCALE FIRE TESTS

A selection of results from the large-scale fire studies is shown in Table 1. The flame spread rates obtained at a given airflow are listed for several different types of conveyor belts. Two tests using double strands of conveyor belt with coal placed on the top belt are also listed in Table 1.

TABLE 1

Airflow effect on 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 *
Same	2.6	0.34
Same	4.1	0.37
SBR, 3 ply, MSHA	0.8	3.0
Same	1.5	5.5
Same	2.6	0.4
Same	4.1	0.0 x
SBR, double strand with coal on top strand	1.5	1.8 (top belt)
Same	4.1	0.6 (top belt)
Neoprene, 1 ply, MSHA	1.5	0.0
Same	4.1	0.0
PVC, MSHA	0.8	0.0
Same	1.5	* *
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

* Flashover (rate of 5.8 m/nin)
** Flashover (rate of 13.7 m/min)
x 0.6 m/min with 3.8 liters fuel added to ignition source

A discussion on these tests is presented later in the section on double strand belt tests. Four types of combustion behavior were distinguished from the large-scale fire tests:

1. no flame propagation over the specimen length and burning limited to the proximity of the ignition zone,

2. slow flame propagation rate (less than 1.5 m/min) with consumption of the specimen,

3. rapid flame propagation termed “flashover" (over 1.5 m/min), which caused scorching of the top surface of the belt with little or no fire damage on the bottom surface of the belt specimen, and

4. rapid flame propagation designated as “flashover” (over 1.5 m/min) with subsequent burning and destruction of the belt.

Analysis of the test results shows that the burning properties of conveyor belts used in underground mines is significantly affected by airflow and the composition of a belt. Under the test conditions, the highest flame spread rates were obtained when the airflow was 1.5 m/set. “Flashover” occurred at an airflow of 1.5 m/set for several types of SBR and PVC belts. At airflows of 0.8, 2.6 and 4.1 m/set, flame spread rates were generally lower than at an airflow of 1.5 m/set. At airflows of 0.8 and 1.5 m/set, smoke and products of combustion spread against the direction of the airflow. Some PVC and chloroprene ‘(neoprene) belts did not propagate flame for the full range of airflows used in the tests, and combustion damage was limited to the ignition zone.

Additional data from the large-scale belt fire studies is presented in the papers by Lazzara and Perzak (4) and Verakis (5).

DOUBLE STRAND BELT TESTS

A limited number of large-scale fire tests were also made at airflows of 1.5 and 4.1 m/set using two strands of conveyor belting. The specimens used for the tests were either SBR or PVC. The test procedures were similar to the single strand tests. The top belt sample was 9.lm long and the bottom belt was 4.6m long. The belt samples were placed on the conveyor structure with the top belt spaced about 0.4m above the bottom belt. Both belts converged within 0.2m of each other in the ignition area. The metal ignition tray was centered under the leading edges of the top and bottom belts. The ignition source consisted of 7.6 liters of liquid fuel.

Analysis of the data from the double strand fire tests also shows that an airflow of 1.5m/sec produced the highest flame spread rate for the test conditions used. “Flashover” also occurred at an airflow of 1.5m/sec for a synthetic rubber and several PVC belts. Flame propagation and combustion damage in the double strand belt tests were greater at an airflow of 1.5m/sec as compared to an airflow of 4.1 m/sec. Combustion damage for one particular PVC belt was limited to the ignition zone when tested at an airflow of 1.5m/sec.

Two tests were also made using double strands of SBR type conveyor belting loaded with run-of-mine coal on the top belt. These tests were conducted at airflows of 1.5 and -1.1 m/set. The top belt was 10.7m long and the bottom belt was 6.lm long. The width of the belt was 1.08m. The amount of coal loaded on the belting was about 53.6 kg/m. The coal loading was 0.20m in height along the centerline of the belt and 0.46m in width. In these 2 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 two to three times higher at the lower airflow than at the higher airflow, A significant rollback of smoke and combustion products against the airflow occurred at the lower, but not at the higher airflow.

DEVEI.OPMENT OF A SMALL-SCALE BELT TEST

One of the program goals in study-ing the fire hazard of mine conveyor belting was to develop an improved small-scale MSHA approval test for fire-resistant conveyor belts. The objectives in developing a small-scale test were:

* to develop an improved approval test for evaluating fire-resistant conveyor belts;
* to attain good correlation/ranking with large-scale belt fire test results;
* to be cost effective, easy to construct, simple to operate and be repeatable.

A program was undertaken by the Bureau of Mines to develop an improved laboratory-scale belt flammability test apparatus for the A&CC. Data from the large-scale belt fire tests were used and such factors as follows were assessed by the Bureau of Mines in developing a new belt flammability test apparatus:

* Scaling of the test;
* type, strength and location of the ignition source;
* size and location of the test sample;
* airflow conditions;
* material properties of the test apparatus;
* environmental concerns.

The amount of belt damage in the large-scale fire tests that occurred at 1.5m/sec airflow was used to establish a pass/fail criterion. A belt would pass if damage by the fire was less than the 9.1m long test sample and an undamaged portion remained across the width of the sample. The selection of this criterion and its application to the large-scale belt test results is presented by Lazzara and Perzak (6). Using the pass/fail criterion for the large-scale test as a basis, a laboratory-scale tunnel test was then developed by the Bureau of Mines. The new apparatus is about 1.8m long by 0.46m square. The belt test specimen used is 0.23m wide by 1.5m long which is about one-fifth the size of belt specimen used in the large-scale tests. A removable, slotted steel rack is used to hold the belt sample about 0.2m from the tunnel roof for testing. A movable methane jet burner is used as the ignition Source. The test is conducted with a jet burner ignition time of 5 minutes and a tunnel airflow of 1m/sec. Detailed features of the new belt evaluation laboratory test (BELT) and the fire testing procedures are described in a document prepared by the Bureau of Mines for the A&CC(7).

Tests on belt samples used in the large-scale fire studies were conducted 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 1.52m length sample remains that is undamaged across its width(7).

Nine different synthetic rubber and eight PVC type belts were evaluated in the laboratory test. 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 foiled the laboratory test; and one failed the large-scale test and passed the laboratory test. A detailed comparison and analysis of the data was published by Lazzara and Perzak (6).

BELT EVALUATION PROGRAM

In January 1989, a public meeting was held at the A&CC to discuss MSHA's Conveyor Belt Flammability Program (8). As part of the meeting, MSHA's future plans for conveyor belt flammability testing and approval were presented and discussed. An interim testing program was subsequently established by the A&CC to further assess the laboratory-scale belt test developed by the Bureau of mines. The testing program is being conducted so conveyor belt manufacturers may obtain flammability data and assess the performance of their belt constructions when evaluated by the laboratory test. Presently, ten conveyor belt companies have participated in the testing program and seventy-nine different belt types have been tested. The types of belts tested have been categorized into four classes and a general summary of the test data is presented in Table 2. Some of the belts tested were experimental in design and the **data** is not intended to represent all types of belt constructions and formulations.

TABLE 2

Summary of test data from A&CC interim test program using the laboratory-scale belt test

Belt Class	Types Tested	Result, Pass/Fail
SBR	6	0/6
PVC	26	14/12
Neoprene	24	18/6
Composites	23	3/20

The test information obtained by each manufacturer should assist in the development of improved fire-resistant belting which will pass the laboratory test.

Through rulemaking, MSHA presently intends to revise its current conveyor belt acceptance test (2G) that is specified in part 18.65 to the more stringent laboratory-scale test which would, in MSHA's view, provide enhanced safety to miners. Concurrent with the rulemaking process, MSHA plans to implement a voluntary acceptance program in December 1989, which would permit conveyor belt manufacturers to submit belts to the A&CC for evaluation using the laboratory-scale test. A belt passing the test would receive an MSHA acceptance number certifying the enhanced fire resistance of the belt. A belt which would be accepted under the voluntary program could then be used underground in compliance with Part 75, Section 75.1108.

SUMMARY

Large-scale belt fire tests were conducted on different types of conveyor belts at airflows ranging from 0.8 to 4.1 m/set. The test results show the highest flame spread rates were obtained when the airflow was 1.5 m/.sec. Data from the large-scale tests Here used with an assessment of test scaling factors and features by the Bureau of Mines to develop a new laboratory-scale test for evaluating the fire 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 fire test data on the performance of their different types of conveyor belting when evaluated in the laboratory-scale test. Following the interim testing program, MSHA plans to revise through rulemaking its present conveyor belt acceptance test to the more stringent laboratory-scale test. In conjunction with rulemaking, MSHA intends to implement a voluntary conveyor belt acceptance program. The voluntary program would enable conveyor belt manufacturers to obtain an acceptance from the A&CC for belts passing the newly developed laboratory-scale test.

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