IMPACT OF ENTRY AIR VELOCITY ON THE FIRE HAZARD OF CONVEYOR BELTS

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ABSTRACT

A Conveyor Belt Fire Test Program was initiated in 1985 by the Approval and Certification Center (A&CC), Mine Safety and Health Administration (MSHA), U.S. Department of Labor. The purpose was GO evaluate the effect of entry air velocities on the burning properties of mine conveyor belts and assess fire test data from large- and small-scale tests. Belts meeting the fire-resistant standards of MSHA and agencies of other countries were tested in small- and large-scale fire tests.

Large-scale tests were made in cooperation with the Bureau of Mines In a surface fire gallery about 27 m long. Fire tests were made at air velocities of 0.8 to 4.1 m/sec.

Small-scale tests were conducted in the 'MSHA "2G Test" apparatus and a laboratory fire tunnel adapted from the German Standard DIN 22118. Tests were made at air velocities of 0 to 1.5 m/sec.

Large-scale test results show rapid flame propagation (flashover) and sustained burning for some belts. However, flashover was not observed in small-scale tests. When flame propagation occurred in the large-scale tests, the rate was generally higher at an air velocity of l.5 m/sec than at lower or higher air velocities. Flame propagation did not occur over the total range of air velocities used for some types of conveyor belts. In general the results of small-scale tests confirm that burning times increase as air velocity decreases.

Test conditions. such as scale of the apparatus, strength of ignition source, and airflow rate,had a significant impact on the, fire test result. The type and composition of conveyor belts have a major effect on burning characteristics. The results from the large- and small-scale tests do not show a direct correlation. Work continues on the development of a small-scale approval test that ranks fire resistance of conveyor belts in approximately the same order as large-scale tests.

INTRODUCTION

Mine fires involving conveyor belts present a serious safety hazard to underground mining. Research and experimental studies on the fire hazard of conveyor belts have-been conducted over many decades and studies continue worldwide.

In the U.S.A., as part of an initiative to develop improved mine safety standards, the current small-scale flame test (2G) was reviewed. Experimental studies were begun to develop an improved test for fire-resistant conveyor belts approved by the Approval and Certification Center (A&CC). The A&CC is part of the Mine Safety and Health Administration (MSHA), an Agency with the U.S. Department of Labor. The major objectives of the initial phase of the program were:

1. to evaluate the effect of a range of mine entry air velocities on the burning characteristics of conveyor belts and
2. to obtain and evaluate flammability test data from large- and small-scale tests.

Conveyor belt- specimens from non fire-resistant (NFR) to fire resistant types meeting MSHA, British Coal, (NCB) and Canadian (CANMET) approval standards were evaluated in both

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TABLE 3

Effect of air velocity on fire damage to conveyor belt in a small-scale tunnel test.

Belt type Sample No.	Air vel. m/sec	LOD* metre
SBR, NFR, 2 ply, A	0.5	1.2
same	1.5	1.2
SBR, MSHA, 2 ply, D-2	0.5	1.2
same	1.0	1.2
same	1.5	1.2
SBR, MSHA 3 ply, D-3	0.5	0.7
same	1.0	1.2
same	1.5	0.9
NP, MSHA 3 Ply, L	0.5	1.2
same	1.0	1.2
same		
NP, MSHA 3 ply, M	0.5	0.7
same	1.0	0.5
same	1.5	0.5
Rubber blend, MSHA, 1 ply, H-3	0.5	1.2
same	1.0	1.1
same	1.5	1.2
Rubber blend, MSHA,1 Ply,K	0.5	0.6
same	1.0	0.5
PVC, MSHA, no ply, N-l	0.5	1.2
same	1.0	0.6
PVC, CANMET, no ply, I	0.5	1.1
same	1.0	0.5
same	1.5	0.6
PVC, NCE, no ply, J	0.5	0.8
same	1.0	0.5

*LOD is the maximum length of belt damage.

SUMMARY AND CONCLUSIONS

Within the scope of this study:

1. Large- and small-scale fire tests were made-on mine conveyor belts using ventilation rates ranging from 0 to 4.3 m/sec.
2. Tests were performed on belts meeting United States, British and Canadian. standards for -fire resistance.
3. Test data were-collected and analyzed on flame propagation, burning the fire damage and combustion-characteristics of the conveyor belts.
4. Large-scale test results show that-for belts which displayed sustained burning for significant lengths,. the flame.: propagation rate was generally higher at an air-velocity of 1.5 m/sec than at higher or lower test-air velocities.
5. A "flashover" phenomenon was observed during the large-scale fire tests with belts composed of SBR* PVC, and an SBR-neoprene combination. For single strand tests, the "flashover" accurred at a ventilation rate of 1.5 m/sec.
6. Sustained burning followed "flashover" for several types of SBR belts. Sustained burning often did not follow "flashover" for those PVC belts tested.
7. During single strand large-scale tests, the rate of flame propagation of a burning belt decreased with increasing entry air velocity and was generally lower at ventilation rates above and below 1.5 m/sec.
8. "Flashover" was not observed in the small-scale tests.
9. The small-scale tests confirm that ventilation rate affects the burning characteristics-of conveyor belts,. Burning times were highest when the air velocity was-decreased to 0.5 m/sec or less (Table 2). For PVC belts, the limited data show that combustion damage increases when the ventilation rate decreases below 1.5 m/sec (Table 3). Synthetic rubber belts displayed no discernible trend in the small-scale tunnel test.
10. In small-scale tests an air velocity of 0.5 m/sec or less generally produced the greatest effect on the burning characteristics of belts. By contrast, an air velocity of l.5 m/sec produced optimum burning results in the large-scale tests.

DISCUSSION

The large-scale fire tests show that "flashover" does occur for some types of belts. A sustained burning of the belt may also occur after "flashover", resulting in consumption of the belt. "Flashover" may occur with just scorching of the belt surface and no sustained burning. "Flashover" represents a severe fire hazard because of the fast rate of flame propagation which can engulf a thousand feet of belting in less than one-half hour.

The small-scale tests previously discussed do not show "flashover". In the large-scale tests, the determination of flame-propagation along the belts was a major objective. In the "2G Test", flame propagation is not measured: how long a belt burns is a parameter of measurement. In the small-scale tunnel test, the amount of fire damage to a belt was the major parameter measured. The nature of the small-scale tests and the parameters measured do not permit direct comparison to the large-scale test results. However, in general, the small-scale tests confirm-that burning times increase as air velocity decreases as shown by velocities of 2.6 and 4.1 m/sec shooed the rate of flame propagation to be less. than obtained at an air velocity of 1.5 m/sec. At air velocities of 0.8 and 1.5 m/sec, smoke and combustion products spread against the direction of airflow.

Some PVC and neoprene belts did not, propagate flame throughout the range of air velocities used. The combustion damage of-such belts was limited to-the ignition zone.

Shepherd and Jones (1952) conducted several large-scale fire tests on a conveyor belt at air velocities of 1.3 and 3.1 m/sec. They found the rate of burning and completeness of combustion increased with increasing air velocity, but the spread of fire along the belt was slow. Shepherd and Jones (1952) also conducted a series of other fire-tests using air velocities of 1.0 to 3.1 m/sec and pieces of conveyor belting about 1 m^2 in area. Their results show the total time of burning of the belting is an inverse function of the air velocity. At 1.0 m/sec and 5.l m/sec, the total time of burning was approximately 270 min and 30 min, respectively.

Mitchell, et al. (1967) conducted large-scale fire tests in a mine entry and in a metal surface gallery. These tests were made on. neoprene, polyvinyl chloride and rubber belts, using air velocities of 1.0 and 2.6 m/sec. A neutral condition was also studied in which no forced ventilation was used. They concluded that flame propagation was not obtained in any test for the neutral air condition. For air velocities of 1.0 and 2.6 m/sec, their results shoved the rate of flame propagation was significantly greater for rubber than for neoprene or polyvinyl chloride belts. However, they did not observe significant differences in flame propagation rates for air velocities of 1.0 and 2.6 m/sec.

At the Third International Congress on Mine Ventilation, A. Frycz and J. Sulkovski (1984) discussed the influence of air velocity on fires involving belt conveyors in coal mines. They state the rate of fire propagation is mainly dependent on the velocity and quantity of air and the amount of combustible material in a heading. Frycz and Sulkowski (1984) refer to an equation from Baltajtis and Markovic (1967) to relate rate of fire propagation to the air quantity divided by the amount of combustible material. A review of the equation using data from Table 1 for a fire-resistant SBR belt shows the Predicted rate of fire propagation would be higher for air velocities of 2.6 and 4.1 m/sec than for l.5 m/sec. However, the test data shows the measured flame propagation rates were nearly equal at 2.6 and 4.1 m/sec. The mass per unit length for the SBR belt was the same in the tests at all three air velocities. At an air velocity of 1.5 m/sec, the measured flame propagation rate for the SBR belt was about three times higher than at 2.6 and 4.1 m/sec.

DOUBLE STRAND TESTS

Several large-scale fire tests were made using double strands of SBR and PVC belts 1.0 to 1.1 m wide. Test procedures were similar to the single strand tests. Air velocities-of 1.5 and 4.1 m/set were used. The top belt was 9.2 m long and the bottom belt was 4.6 m long. The belting was installed on commercially available structure with the top belt 0.4 m above the bottom belt. Both belts converged to a central location in the ignition area. The ignition tray was located under the leading edges of the top and bottom belts.

Preliminary analysis of the double strand test data also shows that an air velocity of 1.5 m/sec produces the optimum burning results for the test conditions. "Flashover" also occurred at an air velocity of 1.5 m/sec for an SBR and several PVC belts. The rate of flame propagation increased by nearly a factor of four for a double strand SBR test at an air. velocity of 4.1 m/sec when compared to a single strand test of the same belt.

SMALL-SCALE TESTS

Small-scale flame tests were conducted by the A&CC in a cubical test apparatus used to evaluate MSHA acceptance of conveyor belts. Synthetic rubber, neoprene and-polyvinyl chloride belt samples were tested to obtain flammability information at several different air velocities.

2G FLAME-TEST

The small-scale regulatory test used by MSHA for acceptance of flame-resistant conveyor belts is commonly known as the "2G Test". The test is specified in the U.S. Code of Federal Regulations, Title 30, Part 18, Section 18.65 (1985).

The "2G Test" is performed in a cubical metal cabinet. The cabinet is 53.3 cm on.a side. A bell-shaped nozzle for the air -inlet (21.6 cm dia. opening), is mounted on one side of the-cabinet. An exhaust opening connected to an electric fan is located on the side opposite-the air inlet.

The test is conducted using a belt sample 15.2 mm long by 1.3 cm wide by its thickness. The sample is secured by a holder inside the cabinet and ignited on the end nearest the air Inlet-by a Bunsen burner. The burner is removed from beneath the sample-after one minute and the exhaust fan is turned on to *create* a ventilation air velocity of 2.5m/sec. The duration of flaming and glowing of the sample is measured. To meet test criteria, the average flame and glow time for four-samples must not exceed 60 and 180 seconds, respectively.

In a series of flame tests, ventilation

TABLE 1

Effect of air velocity on flame propagation rate of conveyor belts in-large-scale tests.

Belt type	Test	Air vel. m/sec	FPR m/min	Comments
SBR (used) 4 ply, MSHA	A5	1.5	0.34	SFP
same	A6	4.1	0.25	SFP
SBR (new) 4 ply, MSHA	G11	1.5	0.24	SFP
same	G12	4.1	0.23	SFP
SBR 1 ply, MSHA	S20	1.5	0.21	FO of 6.1m/min, RFPD
same	S21	4.1	0.00	NFP
Neoprene 1 ply, MSHA	N25	1.5	0.00	NFP
same	N29	4.1	0.00	NFP
SBR (NFR) 4 PlY	GSN33	1.5	+	FO of 7.6 m/min, RFPD
same	GSN30	4.1	0.70	SFP
SBR 4 ply, MSHA	GS37	0.8	0.24	SFP
same	GS31	1.5	0.92	FO of 5.8 m/min, RFPD
same	GS40	2.6	0.34	SFP
same	GS32	4.1	0.37	SFP
SBR/NP 3 ply, MSHA	NSX43	1.5	1.31	FO of 12.8 m/min, RFPD
SBR/NP 1 ply, MSHA	NSY44	1.5	0.00	NFP
PVC, MSHA	P38	0.8	0.00	NFP
same	P42	1.5	0.00	FO of 13.7 m/min, RFPD
same	P39	2.6	0.00	NFP
same	PIO	4.1	0.00	NFP
PVC,CANMET	PE26	1.5	++	FO of 6.7 m/min, RFPD
same	PE28	4.1	0.00	NFP
PVC,NCB	F36	0.8	0.00	NFP
same	F22	1.5	0.00	NFP
same	F41	2.6	0.00	NFP
same	F23	4.1	0.06	NFP

FO Used to designate flashover
\+ Estimated sustained burning rate after FO of 2-2.5 m/min.
++ Estimated sustained burning rate after FO of 0.6 m/min.
+++ No sustained burning rate after FO, but deep char to belt top surface.
NFP, SFP, RFP, and RFPD (Designations as described in text on Results of Large-Scale Tests)

rates were varied from 0 to 1.5 m/sec which is near the maximum air velocity attainable in the MSHA test apparatus. A burner ignition time of 1 minute was used. Some of the "2G Test" results are shown in Table 2. It is apparent from the test data the flame times increase with decreasing air velocity. This data is in agreement with the data of Shepherd and Jones (1952).

TABLE 2

Effect of air velocity on burning time of conveyor belts in the MSHA "2G Test."

Belt type	Air vel. m/sec	Av. burn time sec
SBR, 1 ply, MSHA	0.0	55
same	0.5	43
same	1.0	25
same	-1.5	18
SBR, 3 ply, MSHA	0.0	47
same	0.5	22
same	1.0	20
same	1.5	8
SBR, 2 ply, MSHA	0.0	278
same	0.5	325
same	1.5	37
SBR, 3 ply, MSHA	0.0	28
same	1.5	5
SBR, 8 ply, MSHA	0.0	160
same	0.5	290
same	1.5	30
Rubber blend, 2 ply, MSHA	0.0	157
same	0.5	132
same	1.0	38
same	1.5	9
Neoprene, 3 ply, MSHA	0.0	60
same	1.5	2
PVC, solid woven, MSHA	0.0	20
same	0.5	12
same	1.0	4
same	1.5	3
PVC, solid woven, MSHA	0.0	63
same	1.5	50
PVC, solid woven, MSHA	0.0	13
same	1.5	2
PVC, MSHA, urethane top cover	0.0	119
same	1.5	2

LABORATORY FIRE-TUNNEL

A laboratory fire tunnel described in the German Standard DIN 22118 was modified and used to evaluate the effect of air velocities on combustion properties of conveyor belts. Samples of synthetic rubber, neoprene and Polyvinyl chloride belts were tested at several different air velocities.

FIRE TUNNEL TEST

The laboratory fire tunnel was used to perform a series of belt fire tests. The tunnel is constructed from sheet metal and is lined with rigid insulating material. The test section of the tunnel is approximately 2 m long. The interior of the tunnel is approximately 35.6 cm^2 (0.127 m^2 in cross-sectional area). A heat resistant-glass window about 10 cm wide and 1.6 m long extends along one side of the tunnel to permit viewing.

Smoke and combustion products are removed by an exhaust system connected to one end of the tunnel. A vertical duct which is also connected to the exhaust system, is centered approximately 10 cm above the open end of the tunnel. The duct is used to remove the smoke and fumes which may travel along the roof of the tunnel air escape at the open end. Two mechanical dampers, one located in the exhaust section and one located in the vertical duct, are used to control the ventilation air velocity through the tunnel. The highest air velocity that can be attained in the tunnel is 2.6 m/sec.

A metal holder which slides into the tunnel is used to support a 10 cm wide by 1.2 m long conveyor belt sample. During a test, the belt sample is secured on the metal holder, then moved into the middle of the tunnel and located 10 cm below the roof.

A propane burner, 22.6 cm high with an inside diameter of 3.8 cm, is used as the ignition source. Prior. to a rest, the flow of propane gas to the burner is adjusted to 2 litres/min. This flow rate produces a blue flame 15.2 cm high when the burner is ignited.

During a test, the belt sample is placed in the sample holder and moved into the tunnel. The air velocity is adjusted to 0.5, 1.0; or 1.5 m/sec. The lighted burner i&moved-into the tunnel about 45.7 cm and located under the belt sample for a lo-minute period. After the first 10 minutes, the sample holder is pulled 3.8 cm toward the burner for another 10-minute interval. After the second 10 minutes, the sample holder is pulled 3.8 cm toward the burner and kept in place for another 10 minutes. The total igniting period of the test is 30 minutes. Flame progression along the belt is measured at one-minute intervals After the test, combustion damage along the length of the belt is measured and recorded. A range of conveyor belts were tested at air velocities of 0.5, 1.0 and 1.5 m/sec. Table-3 is a selected listing of conveyor belt test data showing the amount of fire damage sustained at different air velocities. Combustion damage to the PVC belts, tested increased when the air velocity decreased below 1.5 m/sec. A discernible trend in the synthetic rubber belts tested was nor readily apparent.

large- and small-scale flammability tests. The belt compositions were styrene-butadiene rubber (SBR), neoprene (NP), and polyvinyl chloride (PVC).

LARGE-SCALE TEST PROGRAM

Large-scale fire tests were made in cooperation with the Bureau of Mines, U.S. Department of the Interior; in a surface fire gallery simulating a mine entry. The surface gallery consists of an arched fire tunnel having a concrete floor, concrete block walls and a metal roof. The tunnel roof and walls are insulated with ceramic blanket material. The fire tunnel is about 27 m 1ong and is connected to an axial vane fan by a 6 m transition section. The floor is 3.8 m wide and the height to the center of the arch is 2.5 m. The cross-sectional area of the tunnel is 7.5 m^2.

Tests were made using belt specimens 9 to 15 m long and 1.0 to 1.1 m wide... Most tests were made using specimens 9 m long.

Belt specimens to be tested were placed on a commercial belt-carrying structure. The structure was placed on the floor of the tunnel. A mixture of 5.7 litres of kerosene and 1.9 litres of gasoline in a metal tray 0.9 m wide by 0.6 m long was used as the ignition source. The tray was located under the leading edge of the test belt. The ignition area was. shielded to reduce airflow effects on the ignition process.

Fire tests were made using airflow rates of 0.8, 1.5, 2.6 and 4.1 m/sec. Most tests were at airflow rates of 1.5 and 4.1 m/sec. The airflow traveled from the fan through the test area to the exit of the tunnel.

Thermocouples were imbedded in the top surface of the belt specimen along its centerline and about 5 cm from each edge thermocouple spacing of 0.9 m was normally used from the ignition area and continuing along the length of the test belt.

Thermocouple data were-used-to determine flame propagation rates and fire temperatures. Single thermocouples were-located at several points along the tunnel roof and a thermocouple array was placed near the exit of the tunnel.

Several video-cameras were installed in. the tunnel to record the progress of belt fire tests. Measurements of carbon monoxide, carbon dioxide, oxygen and smoke generated during tests were made near the exit of the fire tunnel.

A detailed description of the large-scale fire gallery and, the testing program is presented in papers by Lazzara and Perzak (1987) and Verakis (1986).

FIRE TEST METHOD

Conveyor belts were tested using a-single belt strand placed on the carrying structure. Thermocouples were imbedded in the belt and connected to a data collection system. Instrumentation to obtain information on other fire test parameters, such as carbon monoxide, was also connected to the data collection system. Air velocity was determined from anemometer readings at several points along the belt. Pretest adjustments to obtain a selected air velocity were made by changing the pitch of the fan blades or regulating the inlet to the fan.

Video cameras were started prior to each test. The desired quantity of liquid fuel mixture was introduced into the metal tray. The fuel was then ignited by a match or small torch and fire progress was monitored.

After the test, fire damage to the belt was measured and weight loss of the-belt was determined..

RESULTS OF LARGE-SCALE TESTS

Selected results from the large-scale fire tests are presented-in Table 1. Lazzara and Perzak (1987) also presented some data obtained from the large-scale fire test program. Flame propagation races (FPR) for a chosen air velocity are shown for several representative types of belts tested. In general, four types of combustion features were characterized from the test data:

1. no flame propagation (NFP) over the specimen length and burning limited to proximity of the ignition zone,
2. slow flame propagation (SFP) (less than 1.5 m/min) consuming the belt.
3. rapid flame propagation (RFP) - flashover (FPR greater than 1.5 m/min) - which caused scorching of the top surface of the belt; little or no fire damage to the bottom surface of, the belt, and
4. rapid flame propagation - flashover (FPR greater than 1.5 m/min) - with subsequent burning and-destruction of the belt (RFPD).

Test results show entry air velocity and belt composition have a significant impact on burning characteristics of conveyor belts used in underground mines. Under test conditions, an air velocity of 1.5 m/sec appeared optimum for flame propagation. Flashover occurred at an air velocity of 1.5 m/sec for some PVC and SBR belts.

At air velocities of 0.8, 2.6 and 4.1 m/sec, flame propagation rates were generally lower than at air velocities of 1.5 m/sec. For example, at an air velocity of 1.5 m/sec, flashover at 5.8 m/min occurred on an SBR belt which had a sustained flame propagation rate of about 0.9 m/min. At air velocities of 0.8, 2.6 and 4.1 m/sec, flame propagation rates were approximately one-third the rate at an air velocity of 1.5 m/sec and flashover did not occur.

A comparison of test results at air

Shepherd and Jones (1952).

-Mitchell; et.al. (1967) observed no significant differences in flame propagation. rates for the several air velocities they used. The results of the large-scale tests (Table I) when compared to Mitchell's work (1967) also show for air-velocities above and below 1.5 m/sec the flame propagation rate was generally lower and not significantly different. However, Mitchell (1967) did not make tests at an air velocity of 1.5 m/sec. The large-scale tests do. show significant differences in flame propagation rates for the different types of belts tested.

Flame propagated over the full length of SBR belts tested; "flashover" occurred for several SBR belts when the air velocity has 1.5 m/sec. Flame also propagated over some types of PVC belts as "flashover" with and without sustained burning on the belt surface.

Flame propagation did not occur for an MSHA-accepted neoprene belt and for an NCB-approved PVC belt in the large-scale tests for the range of air velocities used.

The large-scale test results do not show a direct correlation with small-scale tests. The parameters measured in small-scale tests are not necessarily the--same as those measured in the large-scale tests; Test conditions such as, scale of apparatus; procedures; sample size and location; type,. strength and location of ignition source; and ventilation conditions can have major effects on fire test data obtained and on attempts to correlate results and to develop realistic small-scale tests. Experimental belt fire test work is continuing on both large- and small-scale. It is anticipated that a small-scale test can be developed which will rank fire-resistance of conveyor, belts in nearly the same order as is obtained in large-scale tests.. However it is unlikely that a small-scale belt fire test can be developed which will provide direct correlation with large-scale tests and which also produces the phenomenon of "flashover."

REFERENCES

Baltajtis, W.J. and Markowic. J.M., 1967. Method for definition of some parameters of underground fires, based on the analysis of fire gases, Izv. vyssh. uc.heb. Zaved. Gorniy Zh. 10, no. 9. 46-52. (Russian test).

Code of Federal Regulations, Title 30, Part 18, Section 18.65 (Washington, D.C.: U.S. Government Printing Office; July 1985).

Duetsches Institut fur Normung, Conveyor belts with textile plies for coal mining; burning characteristics and testing method, Entwurf Din 22118, December, 1978.

Frycz, A., and Sulkowski, J., 1984. Firefighting in high-methane seams in Polish coal mines, Third International Mine Ventilation Congress, pp. 435-439, Harrogate, England.

Lazzara, C.P., and Perzak, F-J., 1987. Effect of ventilation on conveyor belt fires, Symposium on Safety in Coal Mining, pp. l-15, (Council for Scientific and Industrial Research: Pretoria, South Africa).

Mitchell, D.W., Murphy, E.M., Smith. A.F., and Polack, S.P., 1967. Fire hazard of conveyor belts, United States Department of Interior, Bureau of Mines, Report of Investigations 7053.

Shepherd, W.C.F., and Jones, S., 1952. Investigations into underground fires, The Seventh International Conference of Directors of Safety in Mine Research, pp. l-40, (Safety in Mines Research Establishment: Buxton, England).

Verakis. H-C., 1986. Large-scale fire testing of mine conveyor belts, International Conference on Fire Resistant Hose, Cables, and Belting, pp. 15/l-3, (University of Lancaster: Great Britain).