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RESEARCH TO DEVELOP A SCHEDULE FOR TESTING CONVEYOR BELTS FOR FIRE RESISTANCE

by

S. P. Polack

Presented at Ninth International Conference
of Directors of Safety in Mines Research
Heerlen, Netherlands and Brussels, Belgium
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ERRATA

Page 7. The second sentence in the first paragraph under "Series A tests" should read:

The specimens were 5 inches by 1/2 inch by the thickness of the belt.

Check (X) before the items needing attention.

W.D.W.
Initials of sender.

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INTRODUCTION

The transition of man from stone-age barbarism to the dawn of the atomic era began when man learned to create, control, and utilize fire.

Fire, the benefactor that cooks our food, warms our bodies, turns the wheels of our industries, and illuminates our paths and workshops, can in a brief instant deprive man of the gains of centuries and become his executioner.

Coal-mine fires are usually more dangerous than other underground fires, because, in addition to the restricted operating space and difficulty of approach, the coal itself is highly combustible. To mine coal safely and economically, it is sometimes necessary to bring other combustibles into the mine. A source of ignition is ever present in coal mines and may be electrical, frictional, or thermal. Every fire hazard removed from a coal mine increases the safety factor.

Combustible rubber conveyor belts are an especially dangerous source of fire in coal mines. Test experience to date indicates that this type of belt is readily ignited, and the resulting flame propagates rapidly, spreading destruction and poisonous gases.

Although the use of belt conveyors for coal-mine transportation is relatively new in the United States, the number of conveyors has increased from 359 units using 196 miles of belt installed in 117 bituminous-coal and lignite mines in this country in 1945 to 1,042 units having 608 miles of belt installed in 322 mines at the end of 1953. The average length per unit is 1,541 feet. Three major coal-producing States - West Virginia, Kentucky, and Pennsylvania - have the greatest number of installations - 822, with 474 miles of belt. This does not include main-slope conveyors and those less than 500 feet long. The production from coal mines using this means of transportation in the United States increased from 9 percent of the total output in 1945 to 29 percent in 1953.

A disastrous belt fire in the Cresswell colliery in England caused a loss of 80 lives. This focused attention by all segments of the coal-mining industry on this hazard. Upon analysis, the startling fact was disclosed that the United States Bureau of Mines had investigated over 50 fires from this source in the few years that conveyors have been used to any extent in American coal mines. The loss of life in these fires was small compared with Cresswell, yet four lives were lost in one of them, and greater loss of life is conceivable.

The Federal Mine Safety Code (a set of safety regulations adopted as part of the agreement between the United Mine Workers and the coal operators) refers to "fire-resistant" conveyor belts for underground use, but until recently no means of measuring such resistance was available.

The Director of the United States Bureau of Mines presided at a meeting in July 1954 attended by representatives of coal operators' organizations, United Mine Workers of America, the Rubber Manufacturers' Association, State mining departments, and members of his staff to discuss the belt-fire hazard and suggest remedial action. A research committee was selected and given the following assignments:

1. To determine what qualities a conveyor belt must have to be classed as "fire-resistant."2/

2. To prepare a schedule whereby conveyor belts would be tested for approval and acceptance as fire-resistant.

RESEARCH AND DEVELOPMENT

The necessary research for the first phase was divided into two parts:

(a) Reaction of conveyor belts to applied flame and friction.

(b) Thermal decomposition of conveyor belting at temperatures below ignition point (200° to 300° C.).

Ignition Temperatures of Conveyor Belting

At the beginning of this problem a few samples of rubber, Neoprene, and polyvinylchloride (PVC) belting were prepared for tests to determine the ignition temperatures of these samples. A standard Bureau of Mines ignition-temperature apparatus3/ was used. Results of these tests are shown in table 1. To summarize these results: The minimum spontaneous ignition temperature of rubber, Neoprene, and PVC conveyor belting in air ranged from 403° to 463° C. In an atmosphere of pure oxygen, the ignition temperature range fell to the values 303° to 381° C. Cross sections of the belts were used for testing.

2/ Definition from Webster's New International Dictionary: "Fire resistance: Degree of resistance (of material) to fire. Where determined quantitatively it is measured in terms of time of withstanding a standard test fire."

3/ Zabetakis, M. G., Scott, G. S., and Jones, G. W., The Flammability Characteristics of the C_nH_{2n-6} Aromatic Series: Bureau of Mines Rept. of Investigations 4824, 1951, 9 pp.

TABLE 1. - Summary of ignition-temperature data in air and in oxygen on cross sections of underground conveyor belting

Sample No.	Type of material	In air: Ignition temp., °C.	In air: Time lag before ignition, sec.	In air: Barometric pressure, mm. Hg	In oxygen: Ignition temp., °C.	In oxygen: Time lag before ignition, sec.	In oxygen: Barometric pressure, mm. Hg
1	5-ply PVC	463	14.4	745	381	18.8	742
2	4-ply Neoprene	433	23.7	744	358	28.6	738
7	6-ply rubber	419	23.5	742	328	28.7	744
3	4-ply rubber	416	31.8	742	311	44.3	740
4	do.	406	24.5	742	315	32.3	746
6	7-ply rubber	405	22.1	742	300	34.7	744
5	4-ply rubber	403	33.7	743	303	17.4	745

Flame Tests

A thorough search of available technical literature indicated that the research by the British National Coal Board, Du Pont laboratories, the Rubber Manufacturers' Association (R.M.A.), and German, French, and Netherlands laboratories was illuminating and helpful on the subject of flame tests. The British also had specifications for a drum-friction test.

Finally an American test for fire resistance that appeared adaptable for testing conveyor belting was selected from Standards of the American Society for Testing Materials (ASTM), Flammability of Plastics Over 0.050 Inch Thick, ASTM Designation D635-44.

When the data on flame tests by the ASTM D635-44 method were evaluated and compared with the results of flame tests by some of the methods cited in the publications previously mentioned, using specimens cut from the same samples, it was disclosed that some belts were fire-resistant when tested by the ASTM method and not fire-resistant when tested by R.M.A., English, or Du Pont methods of flame testing. Upon analysis, the outstanding differences in these methods were flame temperatures, mounting of specimens, rate of air flow during testing, and method of evaluating results. After careful consideration of all methods used and incorporation of good features from each a new flame test was devised for testing the fire resistance of conveyor belting and was designated the U. S. Bureau of Mines-American Society for Testing Materials (USBM-ASTM Flame Test). (See fig. 1.)

Flame-Test Apparatus

Figures 2 and 3 are schematic diagrams of the flame-test apparatus. The principal parts of the apparatus are the support stand with a ring clamp and wire gauze a, and a Pittsburgh-Universal bunsen-type burner b (outside diameter of burner tube 13 mm.), mounted in a burner placement guide c, in such a manner that the burner may be placed beneath the test specimen d, or pulled away from it by a knob e, on the front panel of the test gallery f. A variable autotransformer g is used to control an electric fan h, mounted in the wind tunnel i section of the apparatus. Utilizing a standard American Society of Mechanical Engineers (ASME) flow nozzle j (16 to 8-1/2 inches reduction), a nonturbulent air flow can be established within the test gallery, producing ventilation speeds of 50 to 500 feet per minute in the area surrounding the test specimen. If it is desirable to perform flame tests in still air, the wind tunnel and air-flow nozzle can be closed and the cap removed from the vent pipe k. An electric stopclock m facilitates time measurements for the tests. A mirror l, mounted inside the test gallery, makes a rear view of the test specimen through viewing door n possible.

A complete description of the flame-test procedures is contained in section 34.10 of Bureau Schedule 28, Fire-Resistant Conveyor Belts. (See appendix.)

Over 500 test specimens cut from about 90 samples of conveyor belting supplied by 30 manufacturers in the United States, England, France, and Germany were tested using various methods; about 300 specimens were tested by the USBM-ASTM method just described, and the following advantages were noted:

Specimens are tested under controlled ventilated conditions. The evaluation of results is facilitated; instead of recording burning and charring rates and distances, which are difficult to measure, this method allows a reasonable time (1 minute) for belt material to sustain or extinguish flame in a moving air stream after having been exposed to a flame-ignition source.

In practice, this is sufficient for some belts to burn vigorously for lengthy periods, while others extinguish quickly, denoting fire resistance. The time allowed to permit glow to extinguish or kindle is decidedly on the side of greater safety.

USBM Drum-Friction Test

After the establishment and testing of the USBM-ASTM Flame Test, efforts were concentrated on development of a test for conveyor belting to determine the rate and amount of heat due to friction developed in a jammed conveyor belt with the driving pulley turning. To accomplish this the possibilities of purchasing a conventional conveyor and standard conveyor belts were considered. After thorough inquiry, however, a typical underground conveyor, such as is used in coal mines, was procured from another Government agency; and, with the cooperation of the belt manufacturers previously mentioned, enough samples were supplied this laboratory for devising a drum-friction test.

Apparatus

The apparatus is described in section 34.11 of Schedule 28 (appendix). Figure 4 shows final adjustments being made before starting test. The operator is adjusting the air velocity; initial weights and thermocouples are in place.

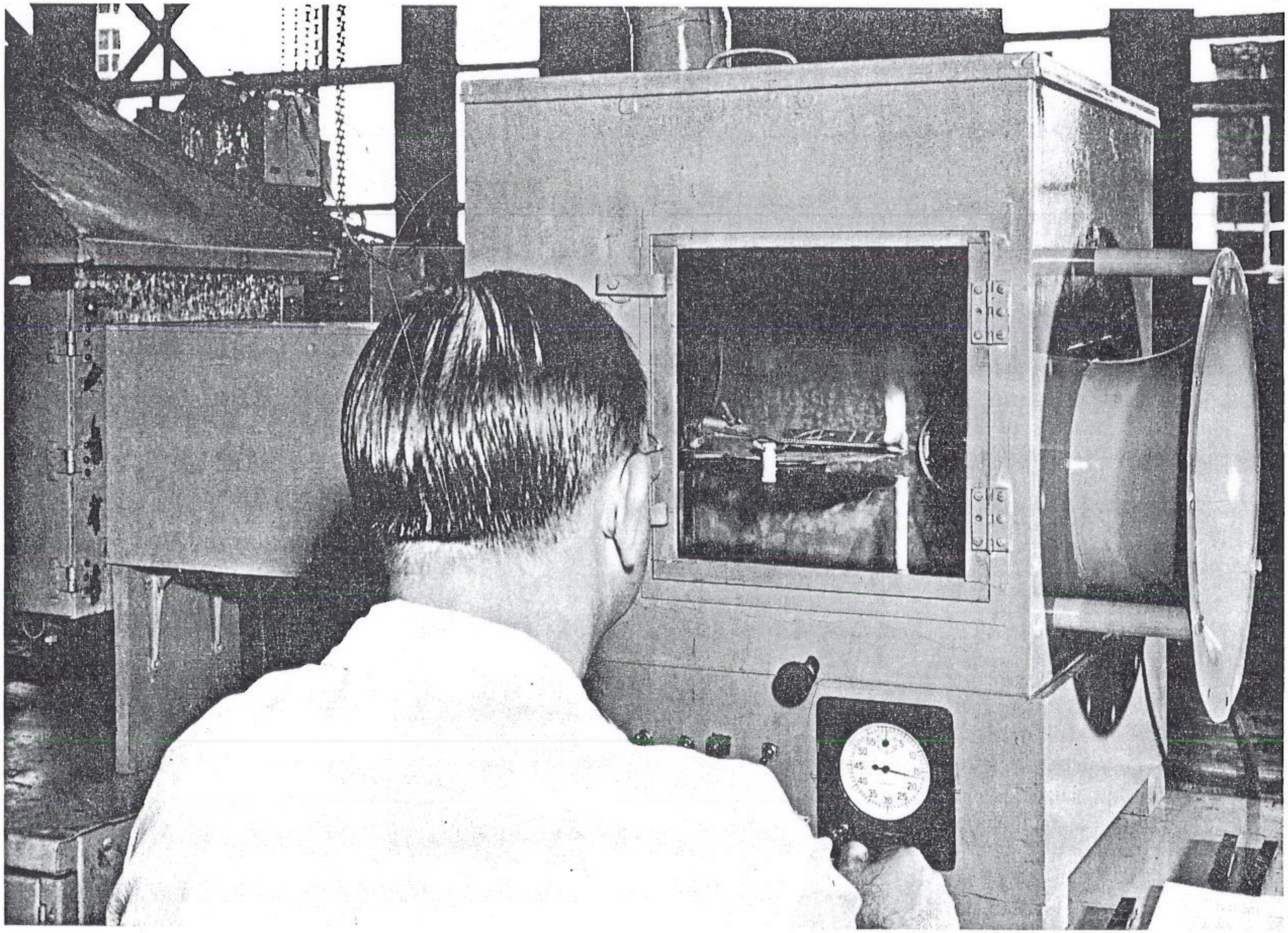


Figure 1. - Flame-test apparatus with test in progress.

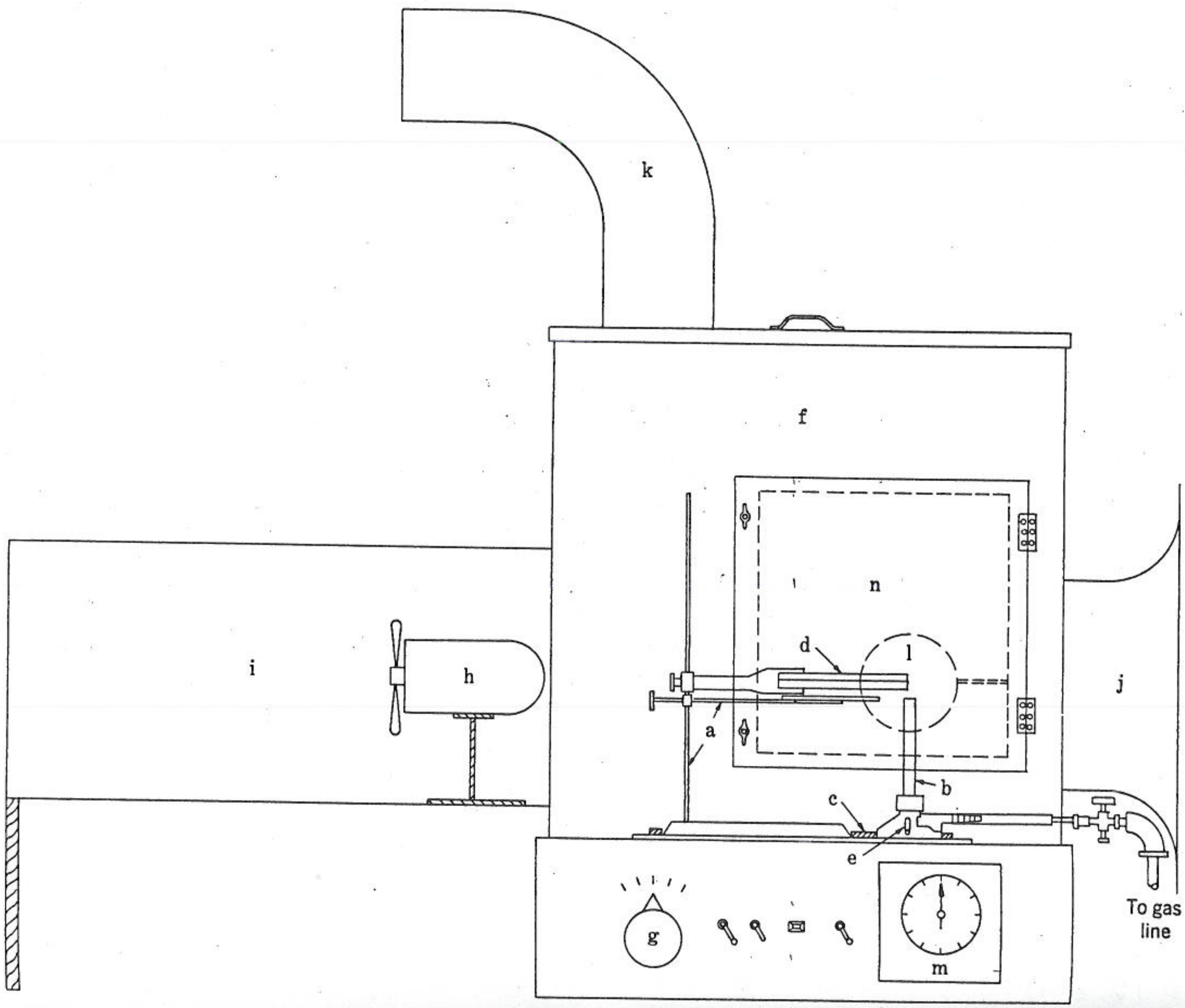


Figure 2. - Schematic diagram of flame-test apparatus

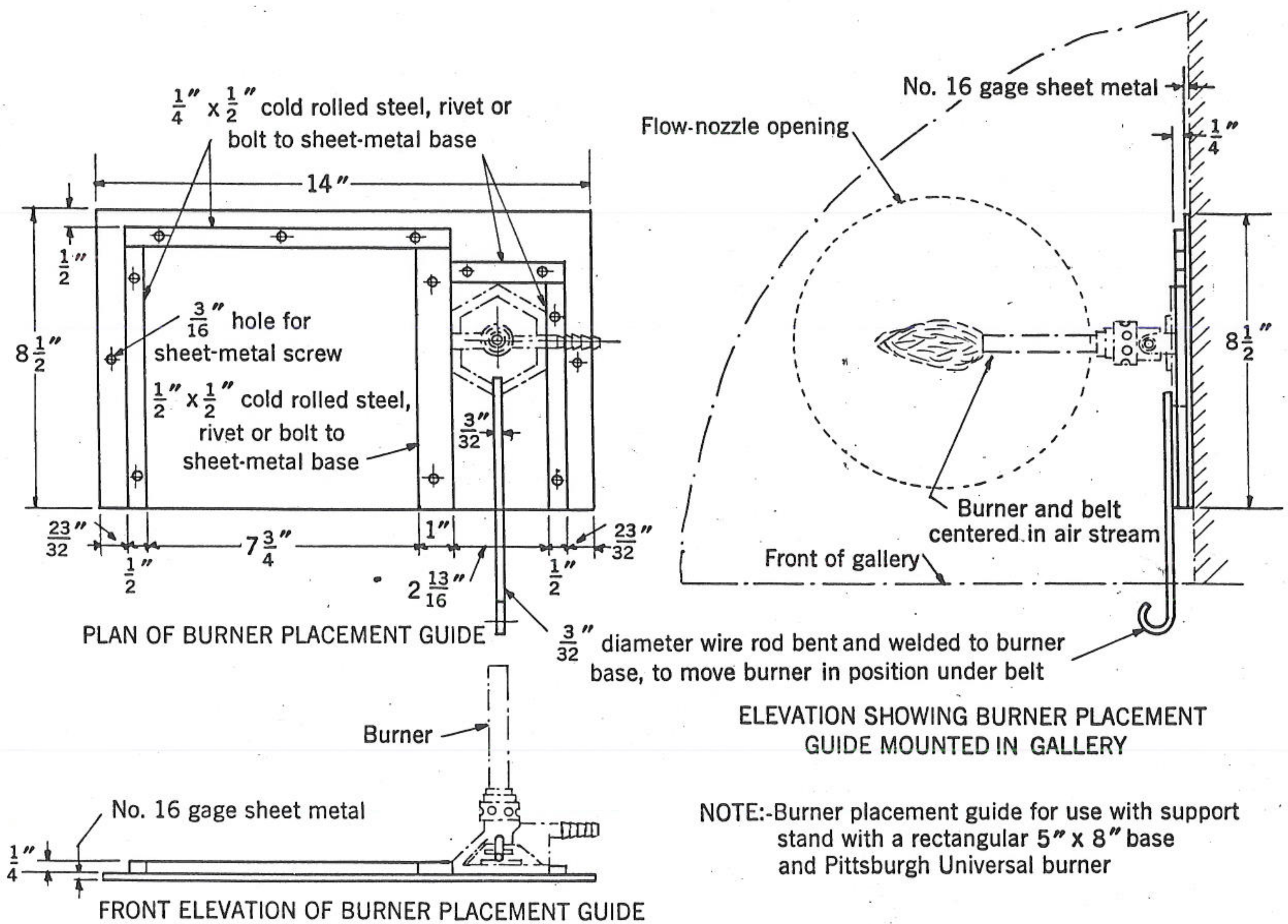


Figure 3. - Details of burner placement guide and location in conveyor-belt flame test gallery.

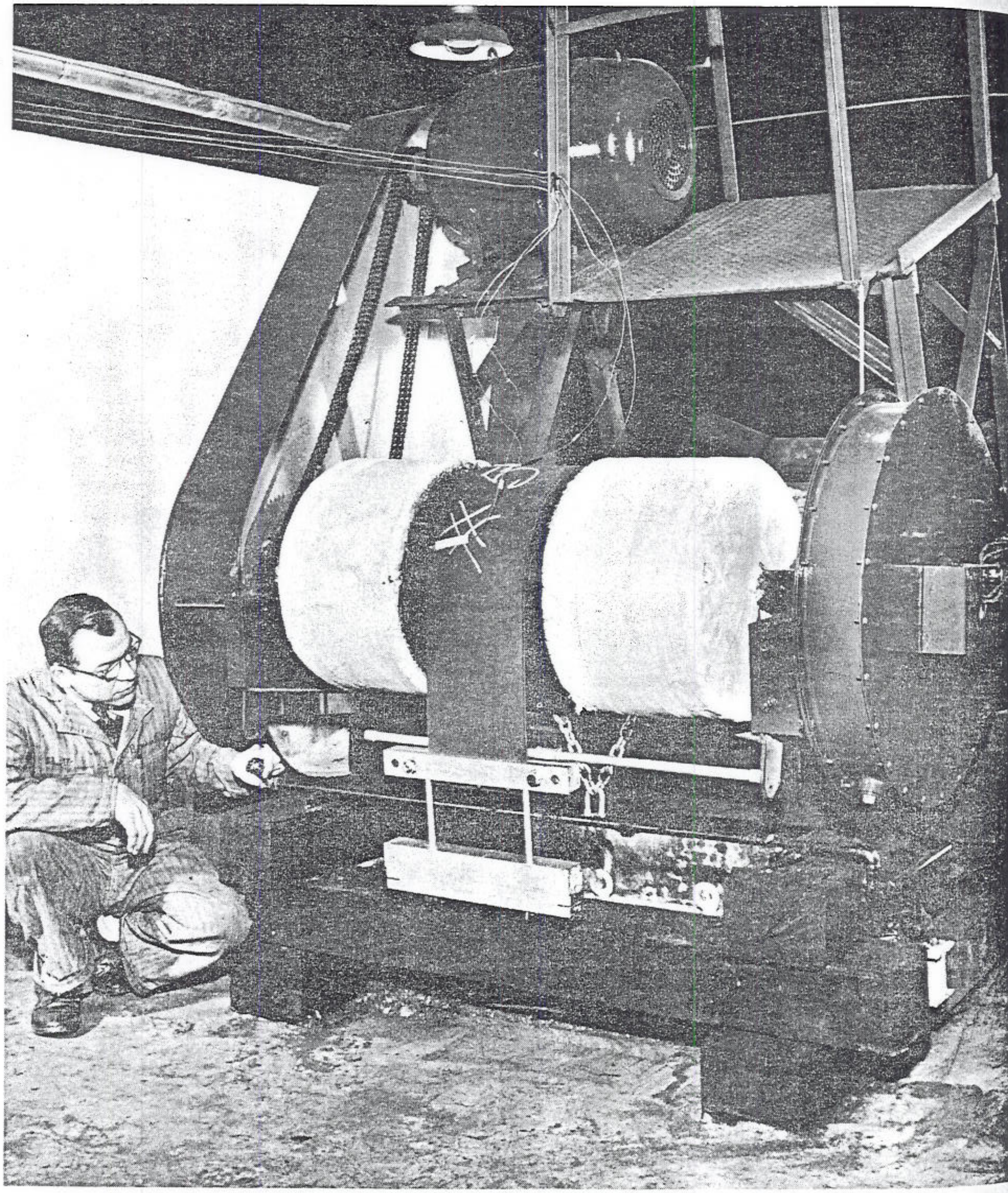


Figure 4. - Drum friction-test apparatus, before starting test.

Procedure

For the preliminary tests no definite system of varying the tension by adding weights to the free end of the belt during a test was decided upon, and the duration of the tests was varied to explore the possibility of gradual accumulation of heat within the belt. Another thermocouple was then inserted on the top of the belt to determine the rate of heat transmission through the thickness of the belt. After the preliminary data were analyzed, a definite pattern was prepared for testing conveyor belts for friction. It was apparent that a 2-hour test was long enough to show the amount and rate of heat developed in a belt under the conditions of an 18-inch-diameter pulley-head turning at 110 revolutions per minute (r.p.m.) (517 feet per minute (f.p.m.) belt speed), provided the following schedule for adding weights was followed:

Duration of test (min.)	Amount of weight added (lb.)	Total weight on free end of belt (lb.)
0	0	50
15	25	75
30	25	100
45	30	130
60	35	165
75	35	200
90	35	235
105	35	270
120	35	305

Under these final conditions for the drum-friction test 38 samples were tested. Three test methods were used, methods A, B, and C. In method A no ventilation was supplied, and no coal dust was added throughout the tests. For method B 300-f.p.m. air current was supplied, and coal dust was introduced between the belt and the driven pulley every 5 minutes. In method C only the air current was applied, and no coal dust was added. The results of these methods are shown graphically in figure 5 for rubber, Neoprene, and PVC (polyvinylchloride). PVC belts were tested by methods A and C only.

Summary of Drum-Friction Tests

The data show that the rubber conveyor belts, such as are used in underground installations today, generate more heat from friction at a faster rate than Neoprene belts. It is evident that the Neoprene belts dissipate the heat more readily. After Neoprene belts reach the temperature range of 180°-220° C. their heating curves level to nearly constant values, in spite of increased friction by the addition of weights to the belts. Some rubber belts burst into flames, others glow red hot, and all of them break before the 2-hour test period is over. To this time Neoprene belts tested by this method did not flame or glow and generally did not break. The addition of coal dust and testing under ventilation aids the rubber belts to flame but does not affect the Neoprene belts appreciably.

Figure 6 shows a rubber conveyor belt set afire during the first 30 minutes of a test. Molten rubber dropping into a pan of pulverized coal on the floor fired the coal.

Due to the limited number of samples, Bureau of Mines experience with PVC is much narrower than that with rubber and Neoprene. However, as no PVC belt survived a complete 120-minute test, we can only say that such belts were destroyed during the test without showing signs of flame or glow. The test procedure is outlined in detail in section 34.11 of the schedule (appendix).

Figure 7 shows 6 belt specimens at the conclusion of drum-friction tests. The 3 Neoprene specimens were subjected to a full 120-minute test and did not flame or glow. The PVC specimen did not flame or glow; however, it was destroyed during the test. The 2 rubber specimens broke, glowed, and flamed during the test.

Figure 8 shows method of cutting samples for flame and drum-friction tests as outlined in Schedule 28 (appendix).

Effect of Heating on the Fire Resistance of Conveyor Belting

During the course of research on conveyor belting resulting in the establishment of the test methods and equipment outlined in Bureau Schedule 28 (appendix), numerous flame tests were performed under the direction of Michael G. Zabetakis, chief, Branch of Gas Explosions, Bureau of Mines, Pittsburgh, Pa., using specimens cut from samples of belting. The ambient temperature of the specimens was elevated to 75°-200° C.; in some instances the bottom (pulley) cover was removed.

The following was concluded: When specimens that were prepared from samples that have passed the flame test at normal laboratory temperature (24° C.) were subjected to the flame test when at elevated temperatures (75°-200° C.), a reduction in fire resistance was noted in some instances.

An experiment was devised to see what changes would occur in the belts after they were preheated to 125° C. for 2 hours and then allowed to cool to room temperature again (24° C.). The samples treated in this manner were flame-tested and the results compared with those of the original flame tests at room temperature. Ten out of twelve of the belts tested had burning or glow times low enough to compare favorably with their original degree of fire resistance. Thus, it has been shown that, in general, moderate heating reduces the fire resistance of a conveyor belt, but when the belt cools or is removed from the source of heat it again approaches the degree of fire resistance it attained at room temperature. Further substantiation of this fact is revealed by the results of flame tests on post-friction belt samples.

Specimens were prepared for flame test from belt samples that were previously given the drum-friction test. During these friction tests temperatures of 195°-274° C. were developed on the pulley-cover side of the belt samples; but, due to the temperature gradient through the belts, the carrying-cover sides were 30°-70° C. lower. This heating by friction is the type to be

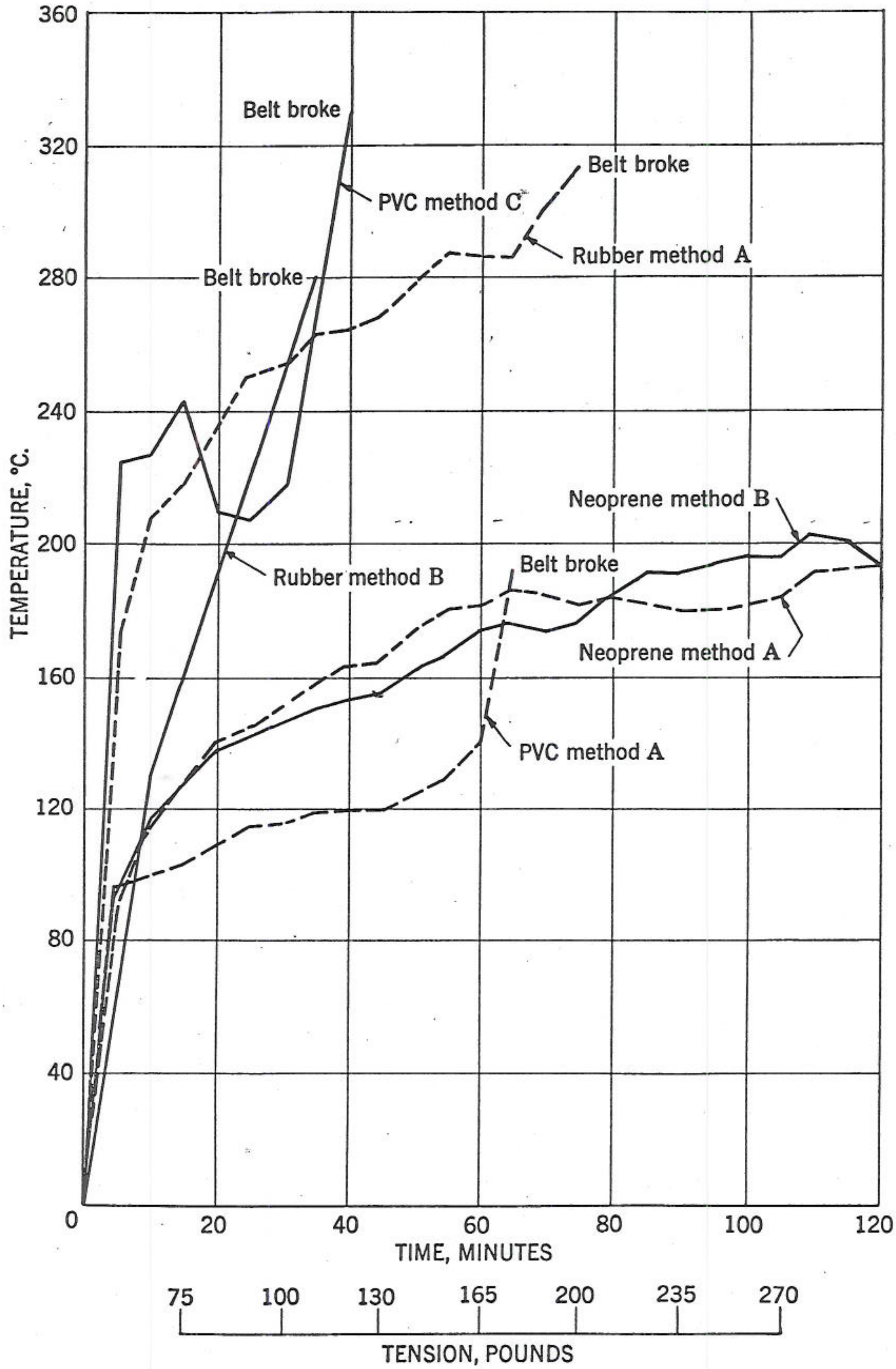


Figure 5. - Time-temperature curves for composite rubber, PVC, and Neoprene belts, methods A, B, and C.

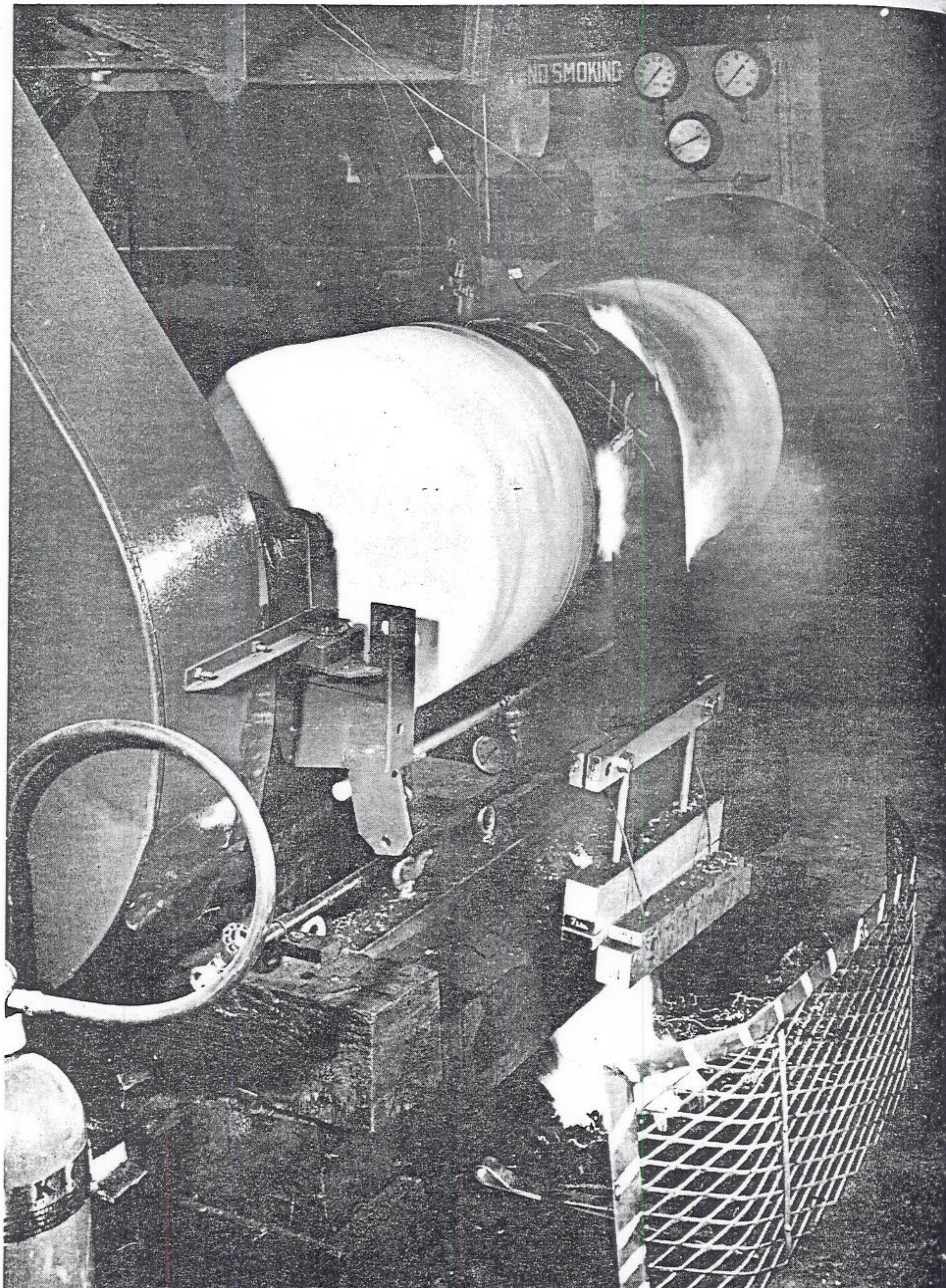
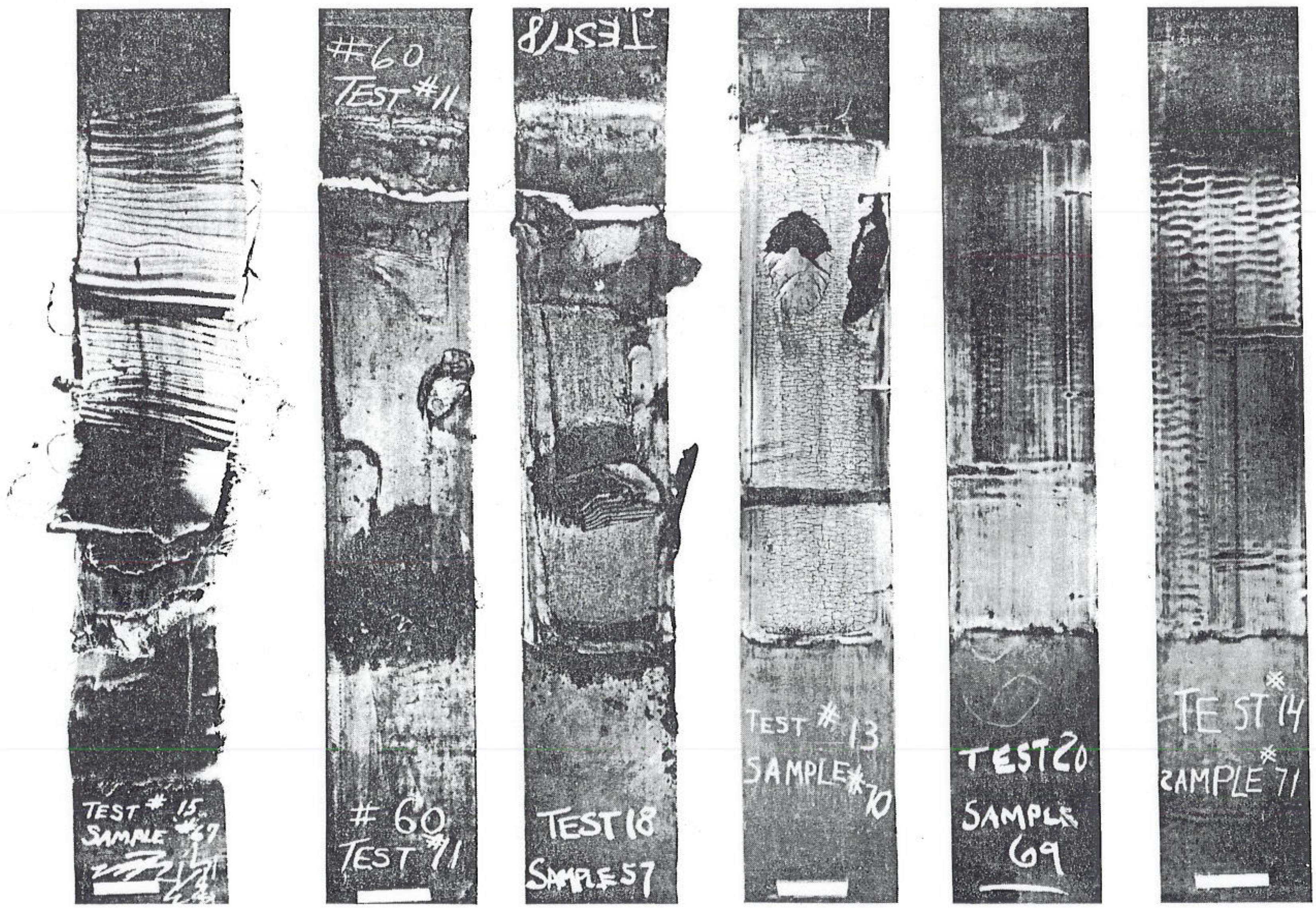


Figure 6. - Rubber conveyor belt set afire during drum friction test.



P. V. C. | Rubber | Rubber | Neoprene | Neoprene | Neoprene

Figure 7. - Condition of 6 conveyor-belt specimens subjected to U. S. Bureau of Mines drum-friction test (method A).

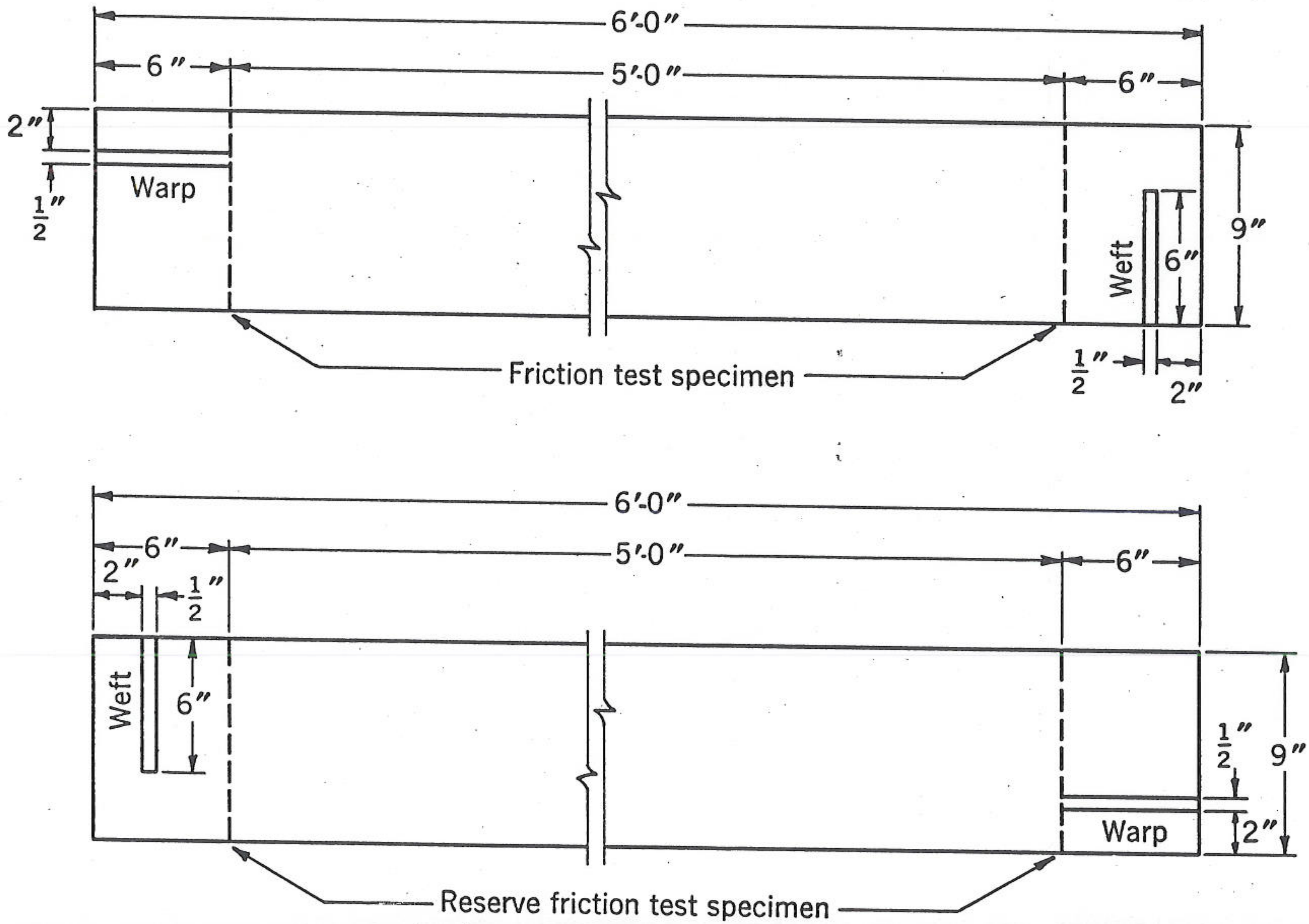


Figure 8. - Method of cutting conveyor-belt samples to obtain specimens for flame- and drum-friction tests

expected in an actual mine installation due to a stalled conveyor belt. After the friction tests in the laboratory were completed and the belts had cooled to room temperature, flame tests were performed. Only one belt showed a marked decrease in fire resistance after these tests. This and the results of thermal decomposition tests discussed later and shown in figures 14 and 15 emphasize the need for devices to stop a conveyor drive automatically when the belt slows or is stopped, even when the belt is fire-resistant. Friction must be avoided if safety and efficiency are to be obtained in belt operation.

Thermal Decomposition and Gas Evolution

The research work pertaining to thermal decomposition and gas evolution was accomplished by the Branch of Health Research under the direction of L. B. Berger, chief of the branch, and H. A. Watson, chief, Gas Analysis and Research Section, Bureau of Mines, Pittsburgh, Pa.

Gases Produced by Combustion and Thermal Decomposition of Conveyor-Belting Materials

Samples of 6 rubber-covered, 7 Neoprene-covered, and 3 polyvinylchloride-covered conveyor belts were subjected to two series of tests to obtain information on the flammability characteristics and the nature and quantities of gases produced when such materials are heated or burned in air:

(1) Series A tests - in which specimens of conveyor-belting materials were burned in air in an enclosed space.

(2) Series B tests - in which specimens of conveyor-belting materials were thermally decomposed by heating in a stream of air at controlled temperatures ranging from 200° to 300° C.

The conveyor belts tested are listed in table 2.

Series A tests

Flammability tests were conducted in which specimens were heated electrically in an essentially airtight chamber (fig. 9) (volume, 270 liters) until ignition occurred and were permitted to burn until flaming and afterglowing ceased. The specimens were 5 inches by ~~long, and their width was~~ 1/2 inch by the thickness of the belt. Time of heating to ignition, duration of flame, duration of afterglow, weight lost from the test specimen, and composition of the resulting gaseous atmospheres were determined.

Summarized data from these tests are given in table 3 and shown graphically in figure 10.

TABLE 2. - List of conveyor belts subjected to combustion and thermal decomposition tests

Identification number assigned to belt	Cover material	Number of plies	Thickness, inches		Polymer content of cover material, percent1/
			Overall	Covers	
8	Rubber	5	9/16	1/16 and 5/32	
19	do.	5	15/32	1/8	
2/45	do.	5	13/32	1/8 and 1/16	
57	do.	4	1/2	1/16 and 1/8	
60	do.	5	15/32	1/8 and 1/32	
63	do.	4	7/16	3/32 and 1/16	
14	Neoprene	5	13/32	1/8 and 1/16	39.8
51	do.	5	7/16	1/8 and 1/32	56.1
52	do.	4	11/32	1/8 and 1/32	48.5
61	do.	5	1/2	1/8 and 1/32	52.1
69	do.	4	7/16	3/32 and 1/16	48.7
70	do.	4	7/16	1/16 and 1/8	51.8
71	do.	5	1/2	1/8 and 3/32	53.3
40	Polyvinyl-chloride	6	1/2	1/16 and 1/16	55.2
41	do.	5	3/8	1/32 and 1/16	45.9
67	do.	5	3/8	1/32 and 1/32	54.8

1/ Cover materials were analyzed for chlorine content; calculated polymer content was based on chlorine content of Neoprene (40.07 percent) and of polyvinylchloride (56.76 percent).

2/ Sample of used belt; original cover thickness - 3/16 and 1/16 inch.

TABLE 3. - Summarized data from series A tests in which specimens of conveyor-belting materials were burned in air in an enclosed space

	Rubber-covered belts1/	Neoprene-covered belts2/	Polyvinyl-chloride-covered belts3/
I. BURNING CHARACTERISTICS			
(1) Time of heating to ignition, minutes			
(a) Range of values	0.74-1.09	1.12-1.96	1.48-4.39
(b) Average value	0.87	1.36	2.43
(2) Duration of flame, minutes			
(a) Range of values	3.27-5.49	.25-4.84	.91-1.60
(b) Average value	4.24	3.24	1.20
(3) Continued smoldering or smoking after disappearance of flame, minutes			
(a) Range of values	4-23	4/0-33	0
(b) Average value	13		

See footnotes at end of table.

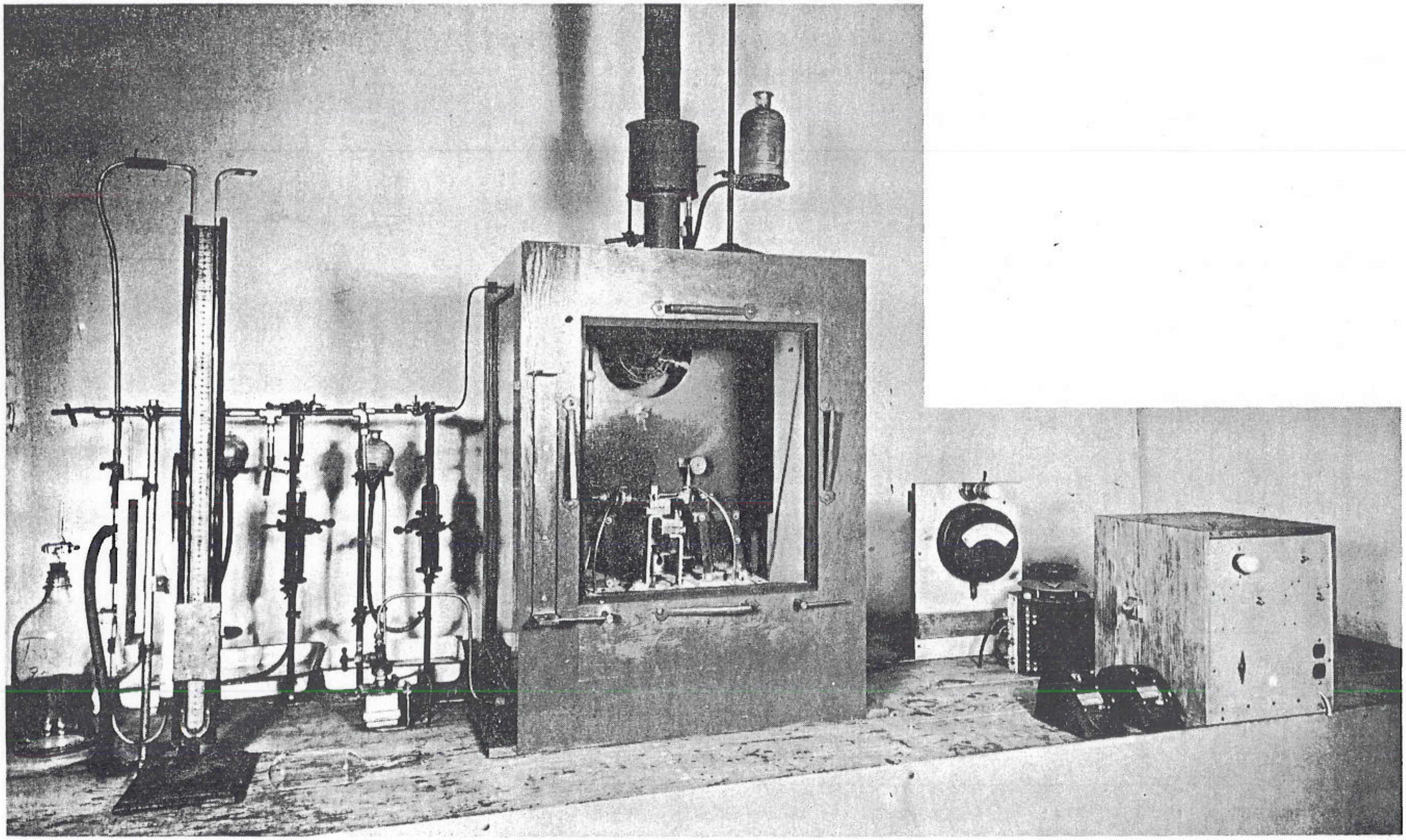


Figure 9. - Test apparatus; general arrangement.

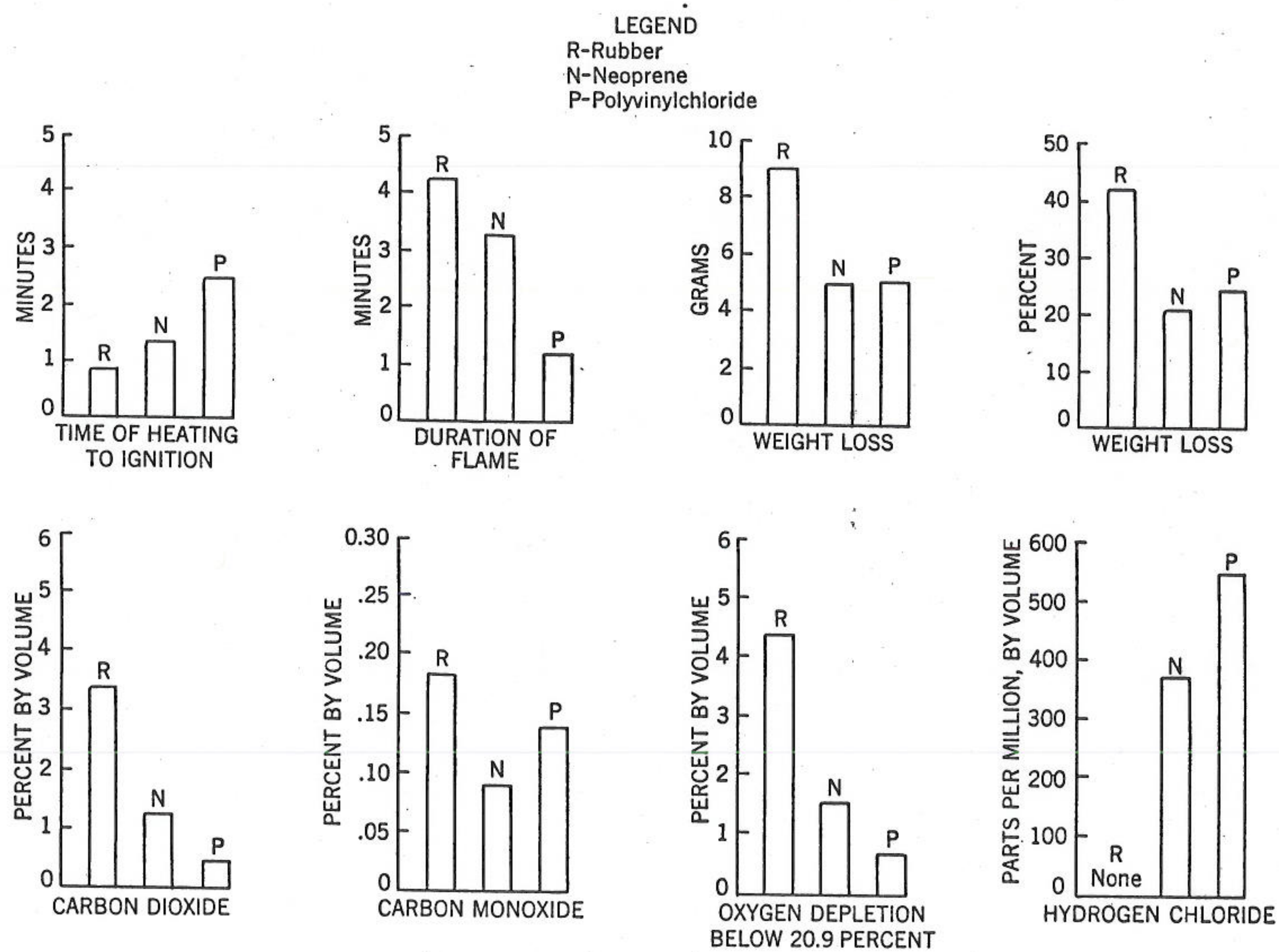


Figure 10. - Summarized data from Series A tests in which conveyor-belting materials were burned in air in an anclosed space. Average values are shown for ignition and burning times; weight loss; concentrations of carbon dioxide, carbon monoxide, and hydrogen chloride; and depletion of oxygen below 20.9 percent in the resulting test atmospheres.

TABLE 3. - Summarized data from series A tests in which specimens of conveyor-belting materials were burned in air in an enclosed space (Con.)

	Rubber-covered belts1/	Neoprene-covered belts2/	Polyvinyl-chloride-covered belts3/
I. BURNING CHARACTERISTICS (Con.)			
(4) Weight loss, grams			
(a) Range of values	6.84-11.20	2.68-7.68	2.82-8.22
(b) Average value	8.96	4.88	5.06
(5) Weight loss, percent			
(a) Range of values	32.9-53.8	8.7-31.4	15.4-38.5
(b) Average value	42.2	20.9	24.4
II. COMPOSITION OF ATMOSPHERES PRODUCED			
(1) Carbon dioxide, percent by volume			
(a) Range of values	3.05-3.76	0.28-2.28	0.37-0.68
(b) Average value	3.36	1.28	0.47
(2) Oxygen, percent by volume			
(a) Range of values	16.95-16.03	20.71-18.09	20.43-20.00
(b) Average value	16.53	19.37	20.28
(3) Carbon monoxide, percent by volume			
(a) Range of values	.10-.32	.06-.13	.09-.19
(b) Average value	.18	.09	.14
(4) Aldehydes as HCHO, parts per million			
(a) Range of values	0-3	0-4	4-14
(b) Average value	2	2	7
(5) Ammonia, parts per million			
(a) Range of values	38-151	2-16	10-77
(b) Average value	79	10	35
(6) Cyanides as HCN, parts per million			
(a) Range of values	0-7	1-13	0-6
(b) Average value	4	9	2
(7) Nitrogen oxides as NO_2, parts per million			
(a) Range of values	10-41	0-22	0-9
(b) Average value	23	9	3
(8) Hydrogen chloride, parts per million			
(a) Range of values	0	29-693	188-926
(b) Average value	0	375	551

1/ 6 belts tested; duplicate tests. 2/ 7 belts tested; duplicate tests.
3/ 3 belts tested; duplicate tests. 4/ Smoldering not detectable in tests of 5 belts; 1 belt smoldered 2 and 4.5 minutes; a second, 26 and 33 minutes.

The rubber-covered materials ignited more readily and burned more vigorously than did the Neoprene-covered and polyvinylchloride-covered materials and suffered more extensive decomposition, as was shown by weight losses, concentrations of carbon dioxide formed, and depleted oxygen concentrations in the resulting gaseous atmospheres. Duration of flame and, hence, extent of decomposition of the rubber-covered materials were limited by the amount of oxygen available in the test chamber. All rubber-covered materials tended to smolder after flaming had ceased. In general, the performance of the Neoprene materials occupied an intermediate position between the rubber-covered and polyvinylchloride-covered materials. Two of the seven Neoprene materials tended to smolder, whereas the polyvinylchloride materials did not.

For the rubber-covered materials, carbon dioxide and carbon monoxide were the most significant gaseous products. For the Neoprene-covered and polyvinylchloride-covered materials, carbon monoxide and hydrogen chloride were the most significant gaseous products; only trace amounts (1 p.p.m. or less) of chlorine or phosgene were detected in any test.

The data obtained in these tests serve for a general comparison of burning characteristics and gas-evolution properties of the three types of materials tested. It is doubted that they may be used justifiably in relation to underground practices, for example, calculation of rate and extent of contamination of mine atmospheres, since test conditions do not duplicate underground conditions. These tests were conducted in an enclosed space in still air (except for convection currents set up by the heating and burning of the specimens), and the duration of burning of the rubber materials - unlike the Neoprene and polyvinylchloride materials - was limited by the available oxygen in the test chamber. If more oxygen had been available in the test chamber, burning of the rubber would have proceeded to a greater extent, and more gaseous products of combustion would have been formed.

Series B Tests

Test pieces (1/4-inch by 1/2-inch by thickness of belt) were subjected to thermal decomposition by heating in a stream of carbon dioxide-free air for 1 hour at controlled temperatures ranging from 200° to 300° C. The effluent gases from the reaction vessel were passed through gas-absorption bottles and collected in a gas reservoir. The contents of the gas-absorption bottles were analyzed for carbon dioxide and hydrogen chloride. The effluent gas mixture in the reservoir was analyzed for content of carbon dioxide, carbon monoxide, oxygen, and combustible gases. Test apparatus is shown in figure 11.

Purpose of Tests

The purpose of these tests was to determine the temperatures at which significant decomposition of the conveyor belts occurred, as indicated by gas evolution. Carbon dioxide, carbon monoxide, and hydrogen chloride were the major gaseous products. Average values and range of values for the volumes of these products per gram of sample at the various test temperatures are shown in table 4 and graphically in figures 12 and 13. A few specimens before and after tests are shown in figures 14 and 15. The most significant result of

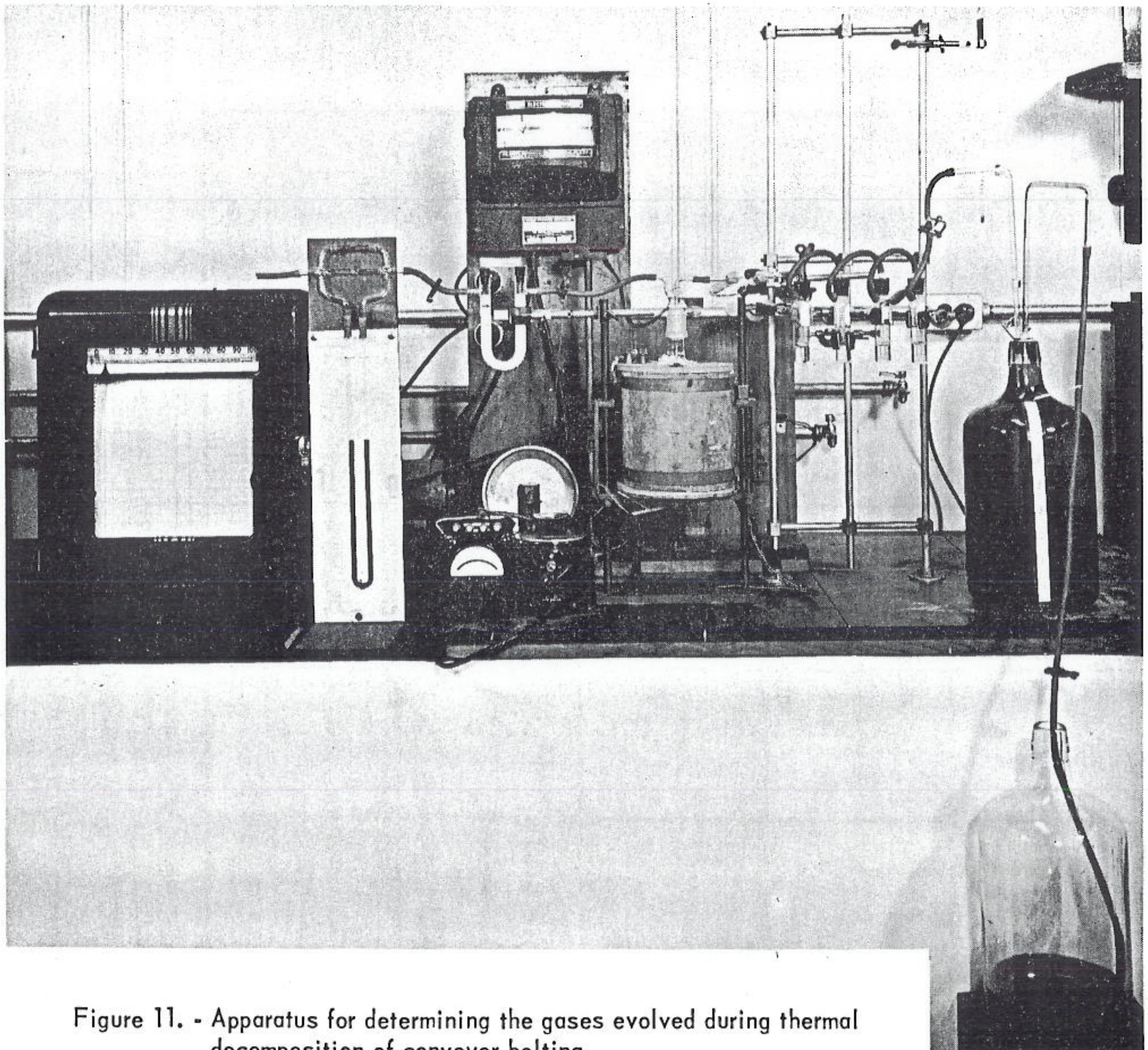


Figure 11. - Apparatus for determining the gases evolved during thermal decomposition of conveyor belting.

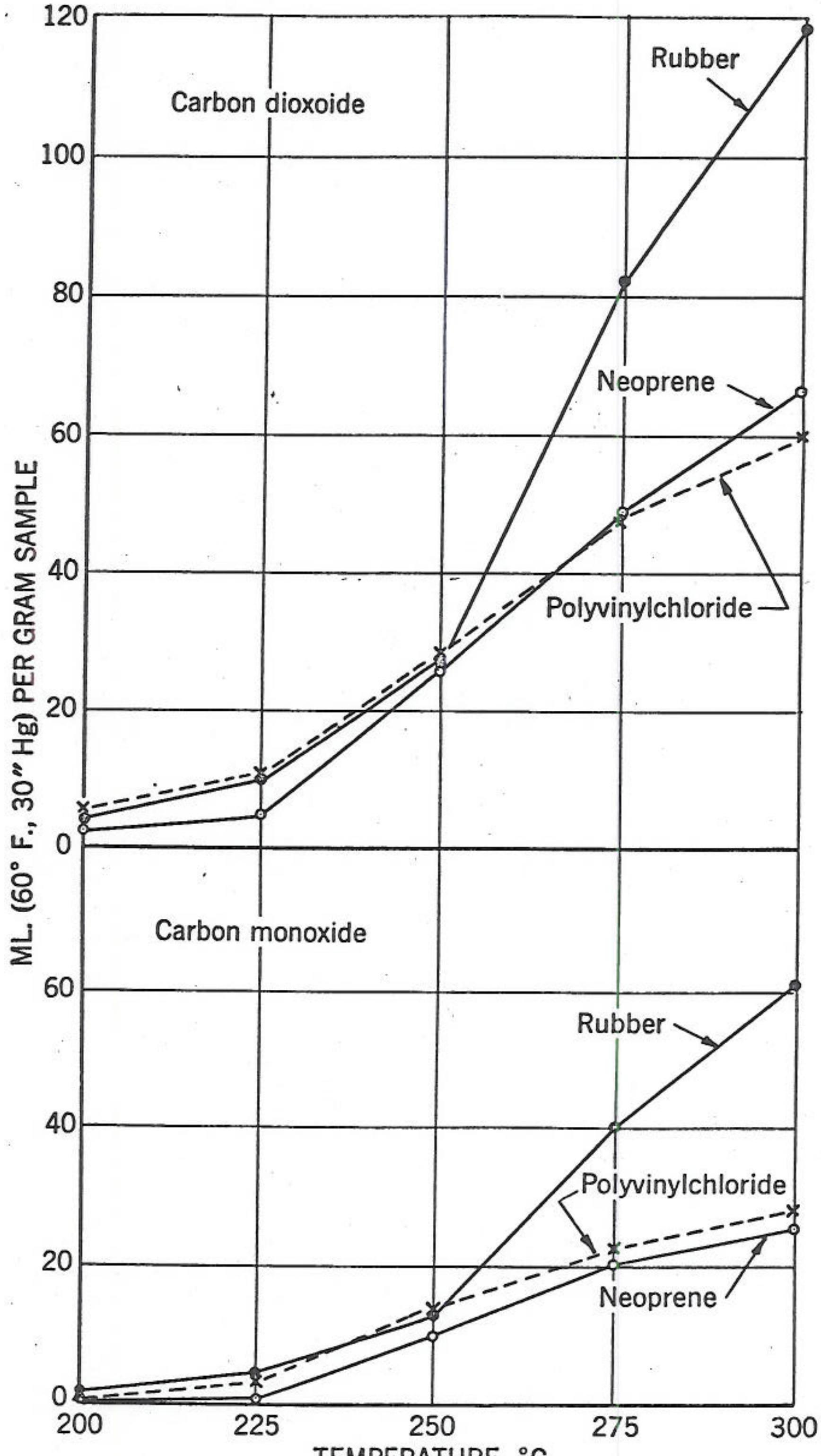


Figure 12. - Series B tests in which conveyor-belting materials were thermally decomposed by heating in a stream of air. Average values are shown for volumes of carbon dioxide and carbon monoxide formed per gram of sample at the various test temperatures.

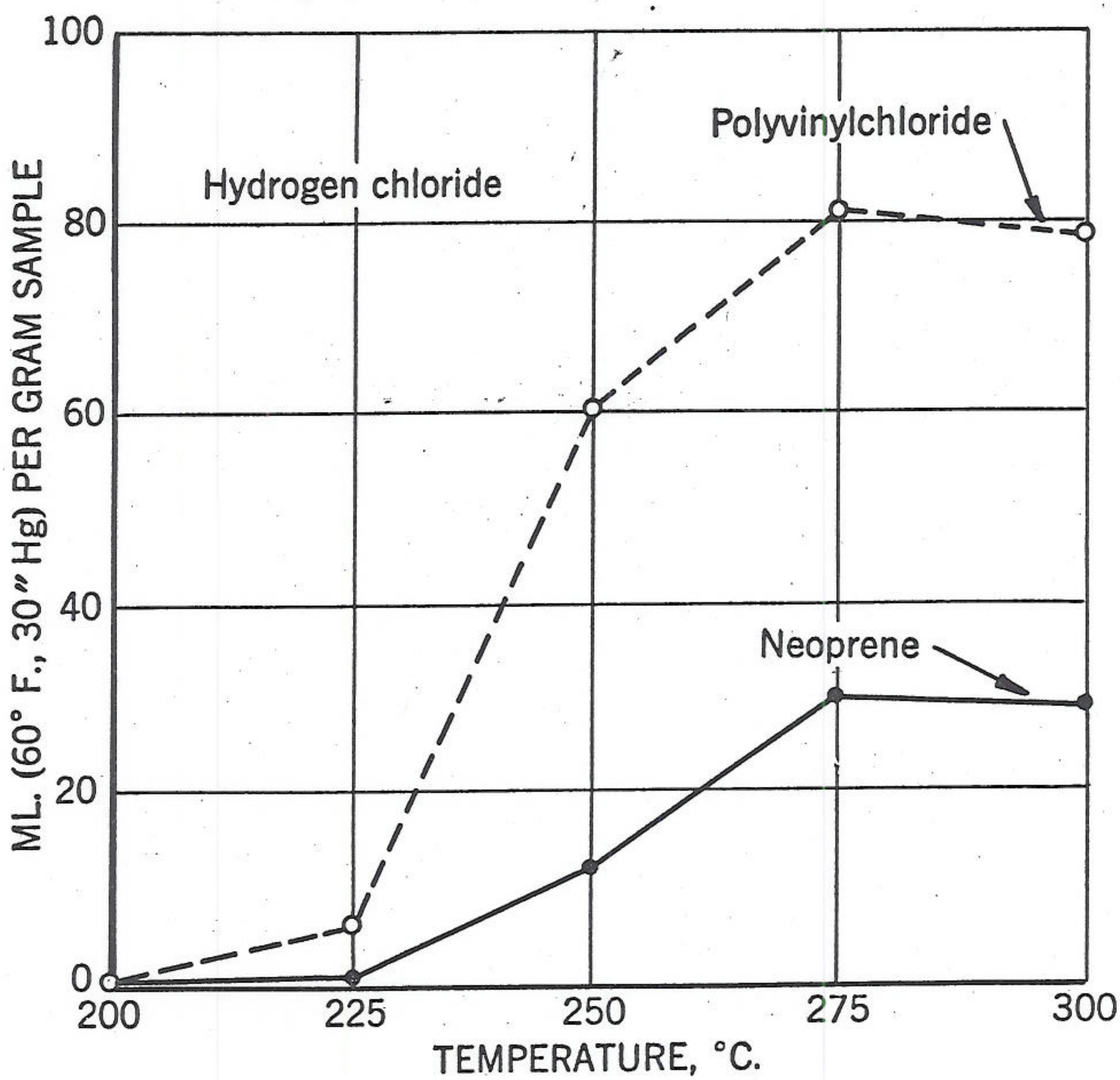


Figure 13. - Series B tests in which conveyor-belting materials were thermally decomposed by heating in a stream of air. Average values are shown for volumes of hydrogen chloride formed per gram of sample at the various test temperatures.

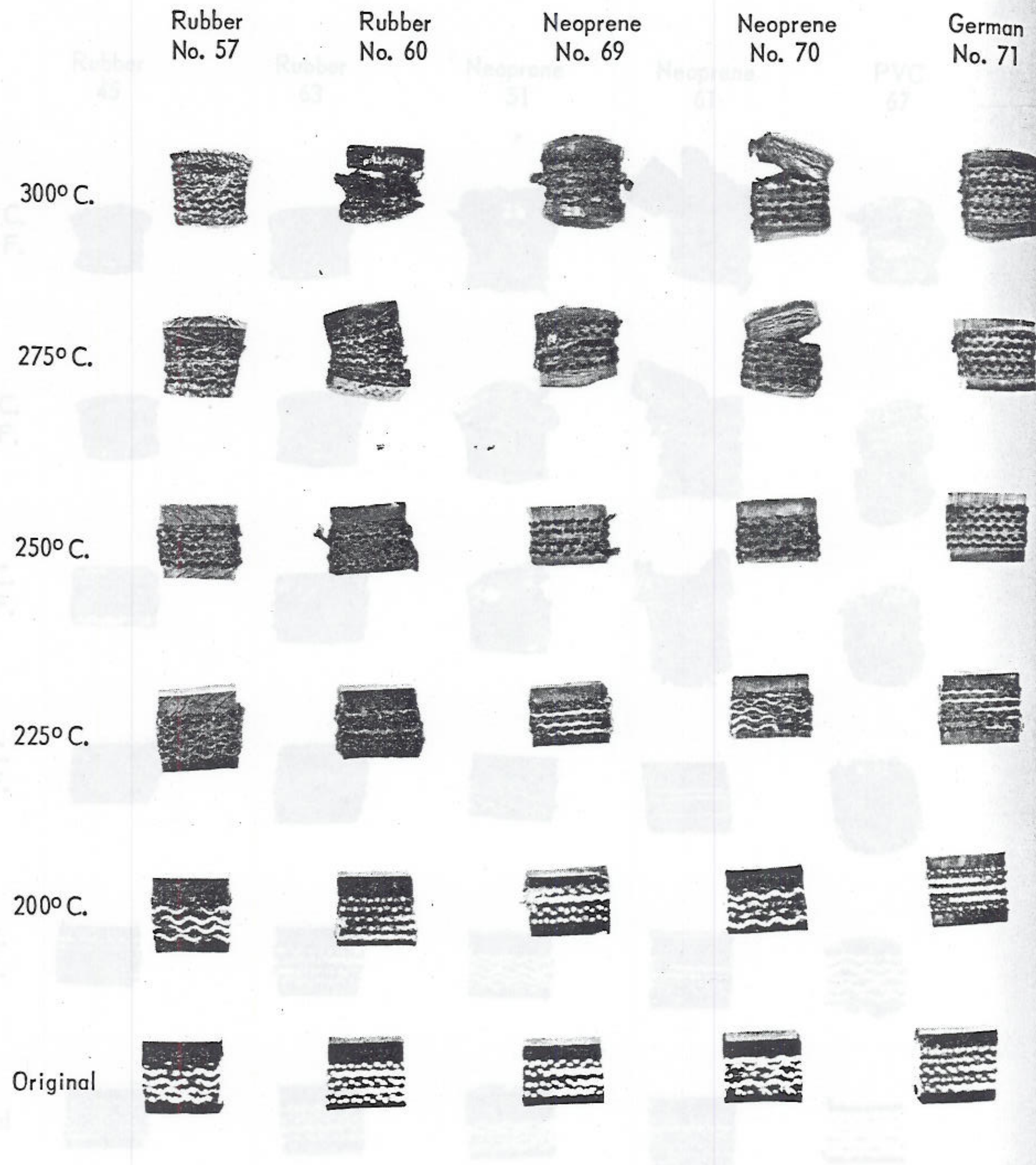


Figure 14. - Specimens of conveyor-belt materials after 1-hour thermal decomposition tests in air.

these tests was the marked increase in decomposition as the temperature was increased above 225° C.

These data may be of value in determining a suitable temperature setting for thermal cutoff devices, if such are used for stopping belt conveyors in case of overheating. It is of some interest to note that 225° C. was the maximum temperature attainable in virtually all drum-friction tests of Neoprene-covered belts. Presumably, as the material starts to decompose with loss of hydrogen chloride at 225° C., the nature of the belt surface changes at the point of contact with the drum, with the result that the characteristics of the frictional contact are altered (by carbonization of the belt surface) and the temperature of the belt ceases to increase. Some observations made during the tests are noted.

TABLE 4. - Summarized data from series B tests in which specimens of conveyor belts were thermally decomposed in a stream of air at controlled temperatures. Average volumes, per gram of sample, of carbon dioxide, carbon monoxide, and hydrogen chloride are shown

Gas	Test temperature, °C.	Volume of gas per gram of sample, milliliters at 60° F., and 30 in. of Hg: Rubber-covered belting[1/]		Neoprene-covered belting[2/]		Polyvinylchloride-covered belting[3/]	
		Range	Average	Range	Average	Range	Average
Carbon dioxide	200	2.1-9.8	4.3	1.2-7.8	2.8	3.0-8.0	6.0
	225	7.8-11.7	10.1	4.3-7.4	5.0	10.9	10.9
	250	7.5-40.9	26.8	12.6-47.5	26.2	18.3-34.4	28.3
	275	65.0-99.5	81.7	39.3-60.6	48.8	47.9	47.9
	300	36.4-182.5	118.8	52.1-83.0	66.4	41.7-70.4	60.2
Carbon monoxide	200	.6-1.9	1.0	.2-.5	.4	.2-.6	.4
	225	3.3-6.1	4.4	.6-1.2	.9	3.5	3.5
	250	4.8-20.9	13.1	2.4-18.9	10.0	7.5-17.4	13.6
	275	32.1-47.7	40.3	14.3-25.9	20.7	22.8	22.8
	300	32.4-73.6	61.0	21.1-32.2	25.8	18.4-35.9	28.4
Hydrogen chloride	200			0-trace	0	.1-.3	.2
	225			.2-.9	.5	6.2	6.2
	250			0-38.3	12.0	44.1-69.2	60.4
	275			10.1-41.6	29.9	81.3	81.3
	300			4.7-47.9	29.3	76.8-81.1	78.7

1/ 6 rubber-covered materials were tested.
2/ 7 Neoprene-covered materials were tested.
3/ 3 polyvinylchloride-covered materials were tested.

At 200° C. small amounts of decomposition products were obtained. At increasing test temperatures the amounts of decomposition products increased rapidly. The amounts of decomposition products yielded by various belt materials differed considerably at comparable test temperatures.

Natural-rubber belts yielded tarry material, an amber-color oily condensate, and carbon dioxide and carbon monoxide. Sulfur dioxide was determined, but only trace amounts were found at the highest test temperatures.

Neoprene belts yielded tarry material, a dark-green paraffin-like condensate and hydrogen chloride, carbon dioxide, and carbon monoxide. German Neoprene belt 71 also yielded volatile antimony compounds.

Polyvinylchloride belts yielded tarry material, hydrogen chloride, carbon dioxide, and carbon monoxide.

SUMMARY

As a result of the research work, Schedule 28 (appendix) was prepared and was legally constituted on November 10, 1955, by publication in the Federal Register, volume 20, No. 220.

When this manuscript was completed, 46 conveyor belts submitted by 9 manufacturers had been tested and accepted for listing as fire-resistant according to the regulations of Schedule 28.

An information circular, Safety Aspects of Controls and Operations of Belt Conveyors in Coal Mines, dealing with the available slippage controls to prevent excessive heating of conveyor belts during operation was prepared by C. L. Brown, Bureau of Mines mining engineer (electrical), who is a member of the research committee, and the manuscript is now in the process of publication.

ACKNOWLEDGMENTS

The cooperation of the members of the research committee, particularly F. E. Scott, chemical engineer, and R. L. Beatty, chemist, both of the Bureau of Mines, who carried out much of the basic research for this problem, and others in the coal-mining and rubber-manufacturing industries at home and abroad who graciously contributed in this effort to reduce the belt-fire hazard, is gratefully acknowledged.

It is the hope of all concerned that mine managements will obtain fire-resistant belts and that the employees who install and operate them will exercise proper care and caution, thus bringing about another advance in mine safety.