

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
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BUREAU OF MINES  
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## REPORT OF INVESTIGATIONS

### STEMMING IN METAL MINES. PROGRESS REPORT 5

COMPARISON OF DUST AND GASES PRODUCED FROM BLASTING CHARGES  
OF DYNAMITE IN DRILL HOLES, IN BOMBS, AND IN MUD-CAP SHOTS



BY

JOHN A. JOHNSON AND WING G. AGNEW



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#### STEMMING IN METAL MINES. PROGRESS REPORT 5<sup>1/</sup>

##### Comparison of Dust and Gases Produced from Blasting Charges of Dynamite in Drill Holes, in Bombs, and in Mud-cap Shots

By John A. Johnson<sup>2/</sup> and Wing G. Agnew<sup>3/</sup>

#### INTRODUCTION

This paper is one of a series being published by the Bureau of Mines pertaining to an investigation on the use of stemming in metal mines now being conducted at the Mount Weather Testing Adit. Its purpose is to compare the amount of dust and gases produced as a result of blasting charges of dynamite (1) in drill holes, (2) in bombs, and (3) in mud-cap or adobe shots.

#### ACKNOWLEDGMENTS

Valuable assistance and advice on stemming were given by members of the staff at the Bureau of Mines, as acknowledged in previous publications.<sup>4/</sup>

#### TEST PROCEDURE

The results used for comparison in this report are from dust and gas samples taken after blasting (1) four regular test rounds with no stemming, (2) five bomb shots, and (3) two mud-cap or adobe shots.

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<sup>1/</sup> The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Report of Investigations 3673."

<sup>2/</sup> Mining engineer, Safety Division, Bureau of Mines, Mount Weather, Va.

<sup>3/</sup> Superintendent, Mount Weather Testing Adit, Mining Division, Bureau of Mines.

<sup>4/</sup> Johnson, John A., Agnew, Wing G., and Mosier, McHenry, Stemming in Metal Mines, Progress Report 1: Bureau of Mines Rept. of Investigations 3509, 1940, 27 pp.; Stemming in Metal Mines, Progress Report 2: Bureau of Mines Rept. of Investigations 3528, 1940, 39 pp.; Stemming in Metal Mines, Progress Report 3: Bureau of Mines Rept. of Investigations 3612, 1942, 16 pp.

The four rounds were the standard 26-hole test rounds designed to break 4 feet of rock. The procedure for drilling and blasting these rounds is described in Report of Investigations 3509.

Before the regular test rounds were blasted, about 1,200 pounds of fine rock was placed on the steel mucking sheets that covered the end of the adit track; the walls, back, and floor of the adit were washed thoroughly; and the fine rock on the mucking sheets was completely wetted.

Each of the 5 bomb shots consisted of 10 sticks of dynamite tied together and hung at midpoint of the adit, 8 feet from the fall.

The conditions of the heading under which each of the bombs was blasted differed slightly and included one or more of the following: (1) No fine rock was on the mucking plates, (2) fine rock on the mucking plates was damp, (3) fine rock on the mucking plates was very wet, (4) fine rock on the mucking plates was dry, (5) sides, back, and face were thoroughly washed down, and (6) damp dust from preceding blast was left on sides and back of the adit.

Each of the mud-cap or adobe shots consisted of 10 sticks of dynamite placed on a large rock 8 feet from the face and covered with wet clay. Two mud-cap shots were blasted with only three sticks of dynamite per shot, but the concentration of gases after blasting was too low to give reliable results.

Forty-percent ammonia gelatin dynamite in 1-1/2- by 3-inch sticks was used in these shots. Dynamite from two 1,000-pound lots manufactured by one company from the same formula was used. The dynamite used in the four test rounds and the five bomb shots had an oxygen balance of +3.85, while that used in the two mud-cap shots had an oxygen balance of +2.11. All shots were detonated by No. 6 electric blasting caps.

The dust and gases after blasting were confined in the heading by a brattice curtain, which was dropped after blasting and nailed securely to a tightly constructed frame. The brattice curtain was dropped immediately after the last shot went off and was securely in place within 2 minutes.

Dust samples were taken with a midget impinger at 3-1/2 to 4-1/2, 12 to 14, and 20 to 22 minutes after blasting, at the midpoint between the face and the brattice. All dust counts were made by the standard light-field microscopic method at a magnification of 100 diameters.

All gas samples were taken by the vacuum-bottle method and sent to the gas laboratory of the Bureau of Mines at Pittsburgh for analysis. After each round was blasted, duplicate gas samples were taken at each of three

locations (one quarter, one half, and three quarters the distance from the face to the brattice) 24 minutes after blasting. After the bomb shots and the mud-cap shots, duplicate gas samples were taken at the midpoint between the face and the brattice 24 minutes after blasting.

A gas sample was taken before blasting each of the shots to determine the amount of carbon dioxide in the air before blasting.

## RESULTS

Table 1 gives the analyses of gas samples of the trapped atmosphere for the four rounds, five bomb shots, and two mud-cap shots. The analyses of carbon dioxide, oxygen, hydrogen, carbon monoxide, methane, and nitrogen are given in percent by volume, while those of oxides of nitrogen are in parts per million.

In the calculations the net percentage of carbon dioxide was found by subtracting the percentage in the blank sample taken before blasting from the percentage in each sample taken after blasting.

Table 2 lists the dust concentrations of the samples taken after blasting, the volume of the trapped atmosphere, the weight of dynamite used in each blast, and conditions in the face region before blasting.

Table 3 shows the dust concentrations, in billions of particles, for each blast, and per pound of dynamite used, of the samples taken 20 to 22 minutes after blasting. This table also shows the cubic feet of gases per pound of dynamite used, and the percentage of recovery of carbon-containing gases. For comparison, the volumes of the gases shown in this table have been converted from prevailing temperatures and pressures to a temperature of 60° F. and pressure of 29.92 inches (760 mm.) of mercury.

The percentage of recovery of carbon-containing gases was calculated by dividing the volume (in cubic feet) of carbon gases obtained by the theoretical volume of carbon gases that could be liberated from 1 pound of dynamite.



TABLE 1. - Gas in percent by volume from samples taken 24 minutes after blasting

Round No.	Weight of dynamite, pounds	Type of stemming and weight, pounds	Gas analysis, percent by volume								Oxides of nitrogen, p.p.m.	Minutes after blasting	Volume of trapped gases, cu.ft.	Remarks
			Gross CO <sub>2</sub>	Blank CO <sub>2</sub>	Net CO <sub>2</sub>	O <sub>2</sub>	H <sub>2</sub>	CO	CH <sub>4</sub>	N <sub>2</sub>				
71	63.00	None	{ 4.78	0.15	4.63	19.00	0.00	0.26	0.08	75.88	248 261	24	3,925	Taken at 1/4 point.
			{ 4.77	.15	4.62	19.00	.00	.26	.08	75.89				Do.
			{ 4.11	.15	3.96	19.36	.00	.20	.09	76.24				Taken at 1/2 point.
			{ 4.10	.15	3.95	19.36	.00	.18	.09	76.27				Do.
			{ 3.77	.15	3.62	19.48	.00	.20	.07	76.48				Taken at 3/4 point.
			{ 3.77	.15	3.62	19.48	.00	.20	.07	76.48				Do.
Average					4.07		.00	.217	.080	254.5				
74	62.74	None	{ 4.26	0.28	3.98	19.19	0.00	0.15	0.10	76.30	314 324	24	4,659	Taken at 1/4 point.
			{ 4.09	.28	3.81	19.29	.00	.14	.09	76.39				Do.
			{ 3.63	.28	3.35	19.44	.00	.14	.07	76.72				Taken at 1/2 point.
			{ 3.60	.28	3.32	19.46	.00	.14	.07	76.73				Do.
			{ 3.35	.28	3.07	19.56	.00	.17	.05	76.87				Taken at 3/4 point.
			{ 3.45	.28	3.17	19.56	.00	.15	.05	76.79				Do.
Average					3.45		.00	.148	.072	319				
81	63.05	None	{ 4.25	0.38	3.87	19.15	0.00	0.20	0.04	76.36	263 263	24	4,515	Taken at 1/4 point.
			{ 4.18	.38	3.80	19.13	.00	.21	.05	76.43				Do.
			{ 3.51	.38	3.13	19.33	.00	.16	.05	76.95				Taken at 1/2 point.
			{ 3.57	.38	3.19	19.33	.00	.16	.06	76.88				Do.
			{ 3.07	.38	2.69	19.62	.00	.13	.05	77.13				Taken at 3/4 point.
			{ 3.32	.38	2.94	19.42	.00	.15	.03	77.08				Do.
Average					3.27		.00	.168	.047	263				
82	62.97	None	{ 3.88	0.23	3.65	19.32	0.00	0.24	0.05	76.51	298 286	24	4,712	Taken at 1/4 point.
			{ 3.88	.23	3.65	19.32	.00	.22	.07	76.51				Do.
			{ 3.77	.23	3.54	19.44	.00	.20	.09	76.50				Taken at 1/2 point.
			{ 3.77	.23	3.54	19.44	.00	.18	.06	76.55				Do.
			{ 2.96	.23	2.73	19.64	.00	.17	.03	77.20				Taken at 3/4 point.
			{ 3.04	.23	2.81	19.64	.00	.17	.06	77.09				Do.
Average					3.32		.00	.197	.060	292				



TABLE 1. - Gas in percent by volume from samples taken 24 minutes after blasting (Cont'd)

Round No.	Weight of dynamite, pounds	Type of stemming and weight, pounds	Gas analysis, percent by volume								Oxides of nitrogen, p.p.m.	Minutes after blasting	Volume of trapped gases, cu. ft.	Remarks
			Gross CO <sub>2</sub>	Blank CO <sub>2</sub>	Net CO <sub>2</sub>	O <sub>2</sub>	H <sub>2</sub>	CO	CH <sub>4</sub>	N <sub>2</sub>				
Bomb 1	7.88	-	1.11	0.45	0.66	20.01	-	0.03	0.00	78.85	589	24	2,968	Sides and back covered with mud; muck on mucking plates damp.
Average			1.12	.45	.67	20.01	-	.03	.00	78.84	589			
					.665			.030	.00		589			
Bomb 2	7.86	-	0.85	0.14	0.71	20.29	-	0.03	0.00	78.83	686	24	2,968	Sides and back of adit washed down; muck on mucking plates very wet.
Average			.82	.14	.68	20.27	-	.03	.00	78.88	650			
					.695			.030	.00		668			
Bomb 3	7.71	-	0.81	0.31	0.50	20.30	-	0.03	0.00	78.86	468	24	4,301	Sides and back covered with mud; no muck on mucking plates.
Average			.82	.31	.51	20.29	-	.03	.00	78.86	451			
					.505			.030	.00		459.5			
Bomb 4	7.67	-	0.55	0.08	0.47	20.56	-	0.03	0.00	78.86	468	24	4,301	Sides and back of adit washed down; no muck on mucking plates.
Average			.55	.08	.47	20.54	-	.03	.00	78.88	494			
					.470			.030	.00		481			
Bomb 5	7.77	-	0.67	0.20	0.47	20.49	-	0.03	0.00	78.81	544	24	4,301	Sides and back of adit washed down; muck on mucking plates very dry.
Average			.66	.20	.46	20.48	-	.03	.00	78.83	544			
					.465			.030	.00		544			
Mud-cap shot 3	7.68	Clay 26.37	0.88	0.17	0.71	20.36	00	0.05	0.07	78.64	230	24	2,468	Dynamite covered with wet clay; rock weighed about 700 pounds.
Average			.92	.17	.75	20.36	00	.04	.08	78.60	216			
					.73			.045	.075		223			
Mud-cap shot 4	7.63	Clay 26.37	0.84	0.10	0.74	20.27	00	0.05	0.04	78.80		24	2,468	Dynamite covered with wet clay; rock weighed about 400 pounds.
Average			.82	.10	.72	20.23	00	.05	.03	78.87	208			
			.82	.10	.72	20.21	00	.05	.02	78.90	209			
					.73			.05	.03		208.5			

TABLE 2. - Dust concentration of entrapped atmosphere after blasting

Round No.	Weight of dynamite, pounds	Type of stemming and weight, pounds	Volume of trapped atmosphere, cu.ft.	Dust concentration, millions of particles per cubic foot of air, minutes after blasting			Remarks
				3.5 - 4.5	12 - 14	20 - 22	
71	63.00	None	3,925	7,280	5,180	3,960	Sides and back of adit washed down before each blast, except where noted. About 1,200 pounds of wet muck put on mucking plates before each blast, except where noted.
74	62.74	None	4,659	7,920	5,920	4,440	
81	63.05	None	4,515	6,660	3,844	3,282	
82	62.97	None	4,712	7,436	5,324	4,010	
Bomb 4	7.67	-	4,301	275	225	133	Sides and back of adit washed down; no muck on mucking plates.
Bomb 2	7.86	-	2,968	570	405	240	Sides and back of adit washed down; muck on mucking plates very wet.
Bomb 3	7.71	-	4,301	320	230	200	Sides and back covered with mud; no muck on mucking plates.
Bomb 1	7.88	-	2,968	700	440	325	Sides and back covered with mud; muck on mucking plates damp.
Bomb 5	7.77	-	4,301	500	420	388	Sides and back of adit washed down; muck on mucking plates very dry.
Mud-cap shot 3	7.73	Clay 26.37	2,468	3,360	2,464	1,860	Dynamite covered with wet clay. Rock weighed about 700 pounds.
Mud-cap shot 4	7.66	Clay 26.37	2,468	1,716	1,570	1,190	Dynamite covered with wet clay. Rock weighed about 400 pounds.

TABLE 3. - Dust concentrations, in billions of particles, from samples taken at midpoint, 20-22 minutes after blasting; cubic feet of gases from samples taken 24 minutes after blasting.

Round No.	Weight of dynamite, pounds	Type of stemming and weight, pounds	Dust concentration, billions of particles		Gas per pound of dynamite, cubic feet, converted to 29.92 inches Hg and 60°F.					Recovery of carbon-containing gases, percent
					CO <sub>2</sub>	CO	CH <sub>4</sub>	Oxides of nitrogen	CO <sub>2</sub> +CO <sub>2</sub> +CH <sub>4</sub>	
71	63.00	None	15,543	247	2.49	0.132	0.049	0.016	2.67	85.6
74	62.74	None	20,686	330	2.49	.107	.052	.023	2.65	84.9
81	63.05	None	14,818	235	2.29	.117	.033	.018	2.44	78.2
82	62.97	None	18,895	300	2.43	.144	.044	.021	2.62	84.0
Average	62.94		17,486	278	2.43	.125	.045	.020	2.60	83.3
Bomb 4	7.67	-	1/ 572	75	2.57	0.164	0.000	0.263	2.73	87.5
Bomb 2	7.86	-	2/ 712	91	2.57	.111	.000	.247	2.68	85.9
Bomb 3	7.71	-	3/ 860	112	2.75	.163	.000	.250	2.91	93.3
Bomb 1	7.88	-	4/ 965	122	2.43	.110	.000	.215	2.54	81.4
Bomb 5	7.77	-	5/1,669	215	2.50	.162	.000	.293	2.66	85.3
Average	7.78		956	123	2.56	.142	.000	.254	2.70	86.5
Mud-cap shot 3	7.68	Clay 26.37	6/4,590	598	2.30	0.142	0.236	0.070	2.68	85.6
Mud-cap shot 4	7.63	Clay 26.37	7/2,937	385	2.30	.158	.094	.066	2.55	81.5
Average	7.66		3,764	491	2.30	.150	.165	.068	2.62	83.7
Comparison of average results										
Rounds	62.94	None	17,486	278	2.43	0.125	0.045	0.020	2.60	83.3
Bombs	7.78	-	956	123	2.56	.142	.000	.254	2.70	86.5
Mud-cap shots	7.66	Clay 26.37	3,764	491	2.30	.150	.165	.068	2.62	83.7

- 1/ Sides and back of adit thoroughly washed down; no muck on mucking plates.
- 2/ Sides and back of adit thoroughly washed down; muck on mucking plates very wet.
- 3/ Sides and back of adit covered with mud; no muck on mucking plates.
- 4/ Sides and back of adit covered with mud; muck on mucking plates damp.
- 5/ Sides and back of adit thoroughly washed down; muck on mucking plates very dry.
- 6/ Rock weighed about 700 pounds.
- 7/ Rock weighed about 400 pounds.



## DUST

Dust samples taken with two midget impingers at different distances from the face (in previous tests) showed that the dust in the trapped atmosphere between the face and the brattice was distributed fairly uniformly at 20 minutes after blasting.<sup>5/</sup> To compare the dust concentrations produced in one blast with that of another blast, the results of dust samples taken 20 to 22 minutes after blasting were used in table 3.

The dust concentrations of the samples taken after blasting the rounds vary slightly, owing to change in the breaking quality of the rock in each round. A tough-breaking rock produces more dust than an easy-breaking rock.

The dust concentrations of the samples taken after blasting the bomb shots show a wide variation, depending on conditions near the face region before blasting. The lowest dust concentration was obtained when the face region was thoroughly washed down and no fine rock was placed on the mucking plates. The highest dust concentration was obtained when dry, fine rock was placed on the mucking plates. Study of the dust concentrations produced from the different bomb shots shows that washing down the back, sides, and face of the heading with water and wetting the fine rock on the mucking plates were decidedly effective in reducing suspension of dust.

Dust concentrations produced by the mud-cap shots varied with the size of the rock blasted. The average concentration per pound of dynamite from the mud-cap shots was higher than that for the rounds and bomb shots.

The dust raised by blasting rounds and mud-cap shots was due partly to breaking rock and partly to the concussion of the blast, while that produced by the bomb shots was due wholly to the concussion of the blast. It would be difficult to say how much of the dust produced by blasting a round was caused directly by the concussion of the blast.

## GASES

Comparison of average results in table 3 shows that about 17 percent less carbon monoxide was produced per pound of dynamite in blasting the rounds than in blasting the mud-cap and bomb shots.

Average results vary greatly in the amount of methane produced per pound of dynamite for the three types of shots. The results show that the

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<sup>5/</sup> Johnson, John A., Agnew, Wing G., and Mosier, McHenry, Stemming in Metal Mines, Progress Report 1: Bureau of Mines Report of Investigations 3509, 1940, 27 pp.



rounds produced 0.045 cubic foot per pound of dynamite, bomb shots 0.00 cubic foot, and mud-cap shots 0.165 cubic foot. Concentration of methane in the samples was very low (less than 0.1 percent) and insignificant as far as mine gases are concerned. As stated, dynamite from one lot was used in blasting the rounds and bomb shots, and dynamite from another lot was used in the mud-cap shots. Several test rounds were blasted with dynamite from each lot, and there was very little variation in the amount of carbon monoxide, methane, or oxides of nitrogen produced per pound of dynamite for the two lots.

The average results show that 0.02 cubic foot of oxides of nitrogen was produced per pound of dynamite in blasting the rounds, 0.254 cubic foot from the bomb shots, and 0.068 cubic foot from the mud-cap shots. The bomb shots produced about 13 times as much oxides of nitrogen as the rounds and about three times as much as the mud-cap shots.

When the three methods of blasting under discussion are considered, the average results show that the method that confined the dynamite least produced the most oxides of nitrogen per pound of dynamite.

In a previous publication of the Bureau<sup>6/</sup> in which were discussed the results of 61 rounds blasted with 60-percent ammonia gelatin dynamite, the results indicate no appreciable difference in the amount of oxides of nitrogen in connection with any of the five types of stemming used, and no stemming.

The average results in table 3 show that recovery of carbon-containing gases ranged from 83.3 to 86.5 percent for the three methods of blasting discussed.

## CONCLUSIONS

Four standard test rounds, five bomb shots, and two mud-cap shots were blasted to determine the amount of dust and gases produced by these three methods.

The bomb shots produced the least and the mud-cap shots the most dust per pound of dynamite.

The dust produced by the bomb shots varied with conditions in the heading - the least was produced when the heading was thoroughly washed down and no fine rock was placed on the mucking sheets, and the most was produced when dry, fine rock was placed on the mucking plates.

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<sup>6/</sup> Johnson, John A., Agnew, Wing G., and Mosier, McHenry, Stemming in Metal Mines, Progress Report 2: Bureau of Mines Rept. of Investigations 3528, 1940, 39pp.

The concentrations of dust produced by the mud-cap shots varied with the size of the rock blasted.

Although the quantities were very small and the differences between types approached the limitation of accuracy for such determinations, apparently less carbon monoxide was produced per pound of dynamite in blasting rounds than in blasting mud-cap shots or bomb shots.

The average results show that the method that confined the dynamite the least produced the most oxides of nitrogen per pound of dynamite. The bomb shots produced about 13 times as much oxides of nitrogen per pound of dynamite as the rounds and about three times as much as the mud-cap shots.

Recovery of carbon-containing gases ranged from 83.3 to 86.5 percent, with an average of 84.5 percent, for the three methods of blasting.



