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*Preliminary Tests of
Overburden Material Filtration and
Capture Bag Concept—Phase*

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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Preliminary Tests of Overburden Material Filtration and Capture Bag Concept—Phase II

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PRELIMINARY TESTS OF OVERBURDEN MATERIAL FILTRATION AND CAPTURE BAG CONCEPT--PHASE II

by

H. L. Horak, W. S. Gregory, P. R. Smith, and H. Grothus

ABSTRACT

The experimental work described in this report was performed to provide test data for the Nuclear Emergency Search Team (NEST) Damage Limitation Working Group. These tests extended our previous test results of shock absorption and aerosol filtration under transient air-flow conditions.

Two types of experiments were run using two separate apparatus. Nylon fabric capture bags were structurally tested on a small shock tube similar to the shock tube used in the Phase I tests but capable of higher-pressure shocks. The various filter media were tested for steady-state aerosol filtration efficiency during high pressure drops using the Phase I blowdown tube modified for thin (2.54 cm or 1 in.) media samples.

I. INTRODUCTION

The experimental work described in this report was performed at the request of Sandia National Laboratories, Albuquerque (SNLA), to provide test data for the Nuclear Emergency Search Team (NEST) Damage Limitation Working Group. This work was a continuation and extension of previous work.¹ These preliminary tests explore techniques of shock absorption and aerosol filtration under transient airflow conditions.

The initial project concept² called for two steps in the tests: (1) determine the aerosol efficiencies of the given materials under steady-state air-flow conditions and (2) determine their efficiencies under simulated blast conditions. The details for the first tests were determined through discussions between SNLA and Los Alamos National Laboratory personnel. These tests were performed at the Los Alamos Fluid Dynamics Test Facility located on the campus of New Mexico State University (NMSU) in Las Cruces, New Mexico.

The results of these tests (Phase I) are reported in detail in our first report on this project.¹ The major results were that

- all materials tested filtered 100% of the aerosol under steady-state conditions and
- the shock tests destroyed two of the three capture bags.

We concluded that more extensive tests (Phase II) were needed to determine the thicknesses for various filtration media that would filter less than 100% of the aerosol under steady-state conditions and to find which capture bag materials withstand the maximum possible shock.

These tests are the subject of this report.

II. SHOCK TUBE TESTS

A. Objective

Our objective was to verify that the nylon capture bag that survived the Phase I shock-tube tests and a heavier nylon capture bag could withstand and dissipate stronger shock waves than those to which they were subjected in the Phase I tests (Fig. 1).

B. Background

Our Phase I experiments subjected three lightweight nylon bags to nominal strength shocks of 69, 138, and 276 kPa (10, 20, and 40 psi). All bags survived the 69- and 138-kPa (10- and 20-psi)-strength shocks. Only one bag

Fig. 1.
Capture bag design behavior.

survived the 276-kPa (40-psi)-strength shock. We decided that shock strengths as high as 517 kPa (75 psi) could be achieved with a moderate-cost apparatus for Phase II experiments.

C. Bag Description

SNLA supplied both bags for the tests. One bag had already survived our Phase I shock tests. The other was a new bag with the same general design but made of heavier (0.475-kg/m^2 or 14-oz/yd^2) nylon material. The design is shown in Fig. 2.

D. Apparatus Description

The shock tube used for these experiments is shown in Figs. 3 and 4. This shock tube is designed for higher strength shocks than the Phase I shock tube, but it works on the same principles.

The tube consists of three sections: a driver (high-pressure) section, an interstage (intermediate-pressure) section, and a driven (ambient-pressure) section.

All sections were fabricated from 58.4-mm (2.3-in.)-i.d. double-extra-strong seamless steel pipe. Steel high-pressure flanges are welded to the ends of all sections, and the sections are connected by bolting the flanges together. A blind flange is used on one end of the driver. The diaphragms are installed between the flanges at each end of the interstage section. The driver and interstage sections are pressurized by a commercial 16.5 MPa (2400-psi) nitrogen gas cylinder through a valving and regulating system.

Fig. 2.
Capture bag dimensions.

Fig. 3.
Schematic drawing of high-pressure shock tube.

Fig. 4.
High-pressure shock tube viewed from the driver end towards the driven end.

The instrumentation consists of two Bourdon-tube pressure gauges (one on the driver section and one on the interstage section), two Kulite pressure transducers mounted 0.305 m (1 ft) and 3.35 m (11 ft) from the muzzle in the driven section, and two copper-Constantan thermocouples [one in the driver section and one in the driven section 1.83 m (6 ft) from the muzzle]. During the test, the instrumentation output was recorded on a Honeywell model 2106 oscillograph. Three SNLA high-speed movie cameras (2 Hycams and 1 Locam) also filmed the bags during the tests. These cameras were aimed at the test bags from different angles.

E. Test Description

The shock tube is prepared for firing by placing two aluminum diaphragms between the flanges that connect the interstage section to the driver section and driven section. The driver and interstage sections are then pressurized. The interstage pressure is maintained at one-half of the driver pressure. The pressure differences between the three sections are maintained at a value less than that needed to rupture the diaphragms. The driver can be pressurized to a maximum of 16.5 MPa (2400 psi), which produces a shock wave with a maximum strength of 483 kPa (70 psi) at the shock-tube muzzle. The cameras and recorder are turned on just before the shock tube is fired. The tube is fired by relieving the interstage pressure rapidly through a solenoid valve. When the pressure in the interstage section falls far enough, the pressure differential between the driver section and the interstage section causes the diaphragm between those sections to burst. The impact of the air against the second diaphragm causes it to break, and a very sharp shock wave forms in the driven section and proceeds down the tube, out its open end, and into the capture bag.

For the test, the bag was mounted on the muzzle (open-end) flange of the shock tube using hose clamps as shown in Fig. 1. The bag was kept horizontal by a string extending from its large end to a support and by string loops extending from an overhead support. The loops also kept the bag collapsed until the shock entered the bag.

F. Test Results

Neither bag broke in any test. The test results are summarized in Tables I (SI units) and II (English units). The pressure-vs-time outputs of the oscillograph are included in the Appendix. The bag behavior could be

TABLE I
BAG-SHOCK TEST RESULTS IN METRIC UNITS

Test No.	Bag ^a	Nominal Pressure Applied (kPa)	Shock Pressure 3.36 m Upstream ^b (kPa)	Shock Pressure 0.31 m Upstream ^b (kPa)	Risetime 3.36 m Upstream ^b (ms)	Risetime 0.31 m Upstream ^b (ms)
1	B	310	265	258	0.5	0.5
2	B	310	331	276	0.5	0.5
3	B	379	375	331	0.5	0.5
4	B	448	441	403	0.5	0.5
5	B	517	524	472	0.5	0.5
6	D	379	386	345	0.5	0.5
7	D	448	430	353	0.5	0.5
8	D	517	532	481	0.5	0.5

^aBag B material: 0.254-kg/m² nylon cloth (white)
Bag D material: 0.475-kg/m² woven nylon cloth

^bFrom mouth of tube

Table II
BAG-SHOCK TEST RESULTS IN ENGLISH UNITS

Test No.	Bag ^a	Nominal Pressure Applied (psig)	Shock Pressure 11 ft Upstream ^b (psig)	Shock Pressure 1 ft Upstream ^b (psig)	Risetime 11 ft Upstream ^b (ms)	Risetime 1 ft Upstream ^b (ms)
1	B	45	38.4	37.5	0.5	0.5
2	B	45	48.0	40.0	0.5	0.5
3	B	55	54.4	48.0	0.5	0.5
4	B	65	64.0	58.4	0.5	0.5
5	B	75	76.0	68.5	0.5	0.5
6	D	55	56.0	50.1	0.5	0.5
7	D	65	62.4	51.2	0.5	0.5
8	D	75	77.1	69.8	0.5	0.5

^a Bag B material: 7.5 oz/yd² nylon cloth (white)
Bag D material: 14 oz/yd² woven nylon cloth

^b From mouth of tube

observed in the high-speed movies, which were copied and distributed to SNLA, Los Alamos, and NMSU.

Both bags behaved as in previous tests when the bag did not break. The shock traveling through Bag D is shown in Fig. 5. However, the bags were somewhat perforated by brass diaphragm shrapnel, and the pressure values from the Kulite pressure transducers did not agree for any test.

G. Discussion of Results

Both bags withstood our maximum-strength shock (approximately 483 kPa or 70 psi) with good dynamic response (identical to our Phase I tests). Thus the capture bag technique is successful at dissipating these shocks. If the bags were found also to adequately filter aerosol particles, they would have application as a vent for explosion containment.

Our apparatus had one anomaly. The pressure transducers indicated a sharp drop in the shock's strength as it progressed down the driver section. We ran 10 additional tests to investigate this phenomenon, and the results are shown in Fig. 6. We believe that this drop is caused by frictional losses resulting from the pipe's roughness.

This relatively low cost shock tube represents the upper shock-strength boundary for its type because of the cost and physical phenomena associated with producing higher-strength shocks. Generating stronger shocks requires

Fig. 5.
Bag D being subjected to a test shock.

Fig. 6.
Pressure loss of shock within the shock tube.

expensive compressed gas and nonstandard pipes and fittings. The safety hazards of high-pressure experimental apparatus are great, and the physical behavior of strong (690-kPa or 100-psi) shocks includes hard-to-predict thermodynamic and heat transfer effects.

III. STEADY-STATE BLOWDOWN TESTS

A. Objective

Our objective was to determine the thickness of filtration material needed to filter approximately 90% of the challenging aerosol. Six materials and aerosols of four different diameters were used. The airflow was caused by a 345-kPa (50-psi) pressure drop across the filtration medium.

B. Background

Our Phase I experiments showed that 0.91-m (3-ft)-thick sections of dry or wet sand, dry or wet vermiculite, or dry earth, and 0.2-m (8-in.)-thick reticulated foam filtered all of the entrained aerosol from air passing through these materials. Therefore, we wanted to determine the material thickness for filtration efficiencies less than 100%.

C. Media Description

Six materials were used as filtration materials: sand, wet sand, vermiculite, wet vermiculite, earth, and reticulated foam. The sand was supplied by NMSU, and SNLA provided the earth, vermiculite, and foam. These materials are the same as those used in the Phase I tests, but their thicknesses were different. A 203-mm (8-in.) thickness was used for reticulated foam, and a 25.4-mm (1-in.) thickness was used for all other materials. The wet material tests were cancelled because the material dried out too quickly (less than 5 min for 1-in.-thick materials).

D. Apparatus Description

The apparatus used in the test is a slightly modified version of the original apparatus (Fig. 7). It is a pipe made of 15.1-cm (6-in.)-diam and 7.62-cm (3-in.)-diam schedule 40 steel pipe, and the fittings are 1724-kPa (250-psig) rated. The inlet air is regulated and filtered and is supplied from two high-pressure air storage tanks. The Retec aerosol generator runs on the same air supply but has a separate regulator. The media fill the test section. Screen (100 mesh) is used to retain the media. Air temperature upstream and downstream of the media is measured by copper-Constantan shielded thermocouples. The pressure drop across the medium is measured by a variable reluctance transducer. The airflow is measured by a Pitot tube and a variable reluctance transducer. The aerosol concentration is determined at the

Fig. 7.
Steady-state blowdown apparatus.

upstream and downstream tees by sampling the airstream and filtering the particles out. The samplers consist of a curved copper sampling tube, a gas-line filter holder with 0.8- μ m-pore-size membrane filter, and a rotometer flowmeter. The upstream sampler vents to ambient air; the downstream sampler vents to a vacuum pump. The modifications to this system were higher capacity rotometers and filter holders in the samplers. The thinner material thicknesses have higher flow rates than before, necessitating the sampler modifications. Because the thickness of the material could vary, the device shown in Fig. 8 was installed to contain the filtration medium at any thickness less than 0.91 m (3 ft.).

E. Test Description

The material to be tested was poured into the test section and secured by the 100-mesh screens. Enough material was added so that the desired material thickness was achieved when it was compacted by a 1455-g (51-oz) weight. The test section was then installed in the apparatus, and the filter membranes were installed in the sampling probes. The aerosol generator was filled with 15 mL of water and a sized latex particle solution (3000:1 dilution) and installed. The Pitot tube was installed, and the main air-supply valve was then opened. The regulator maintained a steady flow with a 345-kPa (50-psi) pressure drop across the test section. The flow velocity profile across the

Fig. 8.
Adjustable-length test material retainer.

downstream face of the test section was checked by a Pitot traverse. Voids in the filtration medium were apparent as high air velocity regions. The vacuum pump and chart recorders (for pressure drop and temperature data) were turned on, and correct airflow was established in the sampling probes. The aerosol generator was started using a 690-kPa (100-psig) setting. The test was run for 35 min, which emptied the generator reservoir, and the system was turned off. The membrane filters were removed from the samplers and sent to the NMSU Biology Department for particle counting using an electron microscope.

F. Test Results

We have listed the major test results in Tables III (SI units) and IV (English units).

G. Discussion of Results

Results from three types of tests are presented. Tests 1--3 determined whether the samples of wet material remained wet; tests 4--6 determined whether the samplers worked correctly and the correct aerosol dilution ratio was used. Tests 7--9 give the aerosol efficiencies of the three materials.

Tests 1--3 showed that the wet materials (sand and vermiculite) dry out in approximately 5 and 4 min, respectively. This time was very short compared to our aerosol efficiency test time and postulated venting time of an actual situation. With the concurrence of SNLA, we discontinued wet material tests.

Tests 4--6 show that a 3000:1 water:latex solution dilution is optimum to get a reasonable number of aerosol counts per 35-min test without agglomeration. Also, they showed that both isokinetic aerosol samplers work.

Tests 7--9 show that 100% of the 0.5- μ m aerosol challenging the material will be filtered out by 25.4-mm (1-in.)-thick samples of dry earth, dry sand, or dry vermiculite. The 25.4-mm (1-in.) thickness is a practical minimum for our experimental apparatus. Also, in a real situation, any overburden material would be much thicker to withstand blast. Thus we believe that the decision to use these materials for blast and aerosol mitigation is determined by their blast behavior.

We also attempted to measure the filtration efficiency of 203-mm (8-in.)-thick reticulated foam. However, the isokinetic aerosol samplers could not operate at the high air velocities (70 m/s or 200 ft/s) necessary to obtain a

TABLE III

RESULTS OF BLOWDOWN TESTS IN METRIC UNITS

Test No.	Material	Aerosol Diam (μm)	Filtration Efficiency (%)	Pressure (kPa)		Temperature (K)	Air Conditions Density (kg/m^3)		Velocity (m/s)		Volumetric Flow (m^3/h)		Material Weight (g)			Dilution (water: latex)	Test Duration (min)
				P_1^a	P_2^b		P_1	P_2	V_1	V_2	Q_1	Q_2	before dry	wet	after		
1	WV ^c	none	-	433.7	88.94	282	5.35	1.09	-	-	-	-	14.8	73.9	13.8	-	30
2	WS ^d	none	-	433.6	88.80	286	5.29	1.09	-	-	-	-	181.2	216.6	172.2	-	23
3	WS	none	-	433.8	89.08	284	5.32	1.09	-	-	-	-	181.2	216.6	173.5	-	5
4	none	0.5	0	88.46	88.46	293	1.06	1.06	11.6	11.6	116.0	116.0	-	-	-	1000:1	35
5	none	0.5	0	88.46	88.46	293	1.06	1.06	11.3	11.3	113.0	113.0	-	-	-	2000:1	35
6	none	0.5	0	88.46	88.46	292	1.06	1.06	11.3	11.3	113.0	113.0	-	-	-	3000:1	35
7	DS ^e	0.5	100	429.6	84.81	284	5.18	1.03	2.82	14.2	138.0	138.0	189.6	-	184.1	3000:1	35
8	DV ^f	0.5	100	433.0	88.26	287	5.26	1.07	2.84	13.9	141.0	141.0	-	-	21.0	3000:1	35
9	DE ^g	0.5	100	433.1	88.39	286	5.24	1.07	1.43	7.04	71.3	71.3	172.5	-	166.0	3000:1	35

^aSubscript 1 = upstream of material.^bSubscript 2 = downstream of material.^cWV = wet vermiculite.^dWS = wet sand.^eDS = dry sand.^fDV = dry vermiculite.^gDE = dry earth.

TABLE IV

RESULTS OF BLOWDOWN TESTS IN ENGLISH UNITS

Test No.	Material	Aerosol Diam (μ m)	Filtration Efficiency (%)	Pressure (psig)		Temperature (K)	Air Conditions Density (lbm/ft ³)		Velocity (ft/s)		Volumetric Flow (ft ³ /h)		Material Weight (g)			Dilution (water: latex)	Test Duration (min)
				P ₁ ^a	P ₂ ^b		P ₁	P ₂	V ₁	V ₂	Q ₁	Q ₂	before dry	wet	after		
1	WV ^c	none	-	62.90	12.90	508	0.334	0.068	-	-	-	-	14.3	73.9	13.8	-	30
2	WS ^d	none	-	62.88	12.88	514	0.330	0.068	-	-	-	-	181.2	216.6	172.2	-	23
3	WS	none	-	62.92	12.92	512	0.332	0.068	-	-	-	-	181.2	216.6	173.5	-	5
4	none	0.5	0	12.83	12.83	527	0.066	0.066	38	38	4.1 x 10 ³	4.1 x 10 ³	-	-	-	1000:1	35
5	none	0.5	0	12.83	12.83	527	0.066	0.066	37	37	4.0 x 10 ³	4.0 x 10 ³	-	-	-	2000:1	35
6	none	0.5	0	12.83	12.83	525	0.066	0.066	37	37	4.0 x 10 ³	4.0 x 10 ³	-	-	-	3000:1	35
7	DS ^e	0.5	100	62.30	12.30	512	0.323	0.064	9.26	46.8	4.88 x 10 ³	4.89 x 10 ³	189.6	-	184.1	3000:1	35
8	DV ^f	0.5	100	62.80	12.80	517	0.328	0.067	9.32	45.6	4.99 x 10 ³	4.99 x 10 ³	-	-	21.0	3000:1	35
9	DE ^g	0.5	100	62.82	12.82	516	0.327	0.067	4.7	23.1	2.51 x 10 ³	2.52 x 10 ³	172.5	-	166.0	3000:1	35

^aSubscript 1 = upstream of material.^bSubscript 2 = downstream of material.^cWV = wet vermiculite.^dWS = wet sand.^eDS = dry sand.^fDV = dry vermiculite.^gDE = dry earth.

345-kPa (50-psi) pressure drop across the foam. No aerosol particles reached the upstream sampler membrane filter.

IV. CONCLUSIONS

These tests suggest that the capture bag shock attenuation and the overburden filtration concepts work up to the limits of our test apparatus. Further testing of either concept would require additional new apparatus and instrumentation.

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2. F. W. Gelbard, "Scope of Work Letter," Sandia National Laboratories, Albuquerque, to W. S. Gregory (April 1979).

APPENDIX

SHOCK-TUBE PRESSURE DATA TRACES

Fig. A-1.
Test No. 1 pressure data traces
(Bag B).

Fig. A-2.
Test No. 2 pressure data traces
(Bag B).

Fig. A-3.
Test No. 3 pressure data traces (Bag B).

Fig. A-4.
Test No. 4 pressure data traces (Bag B).

Fig. A-5.
Test No. 5 pressure data traces (Bag B).

Fig. A-6.
Test No. 6 pressure data traces
(Bag D).

Fig. A-7.
Test No. 7 pressure data traces
(Bag D).

Fig. A-8.
Test No. 8 pressure data traces (Bag D).

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