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EFFICIENCY OF FIBER DISPERSION

C. W. Bruce and Mike J. Thurston
U.S. Army Research Laboratory

A. V. Jelinek
Physical Science Laboratory

ARL-TR-56

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C. W. Bruce, Mike J. Thurston, and
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U.S. Army Research Laboratory
Battlefield Environment Directorate
ATTN: AMSRL-BE
White Sands Missile Range, NM 88002-5501

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U.S. Army Research Laboratory
2800 Powder Mill Road
Adelphi, MD 20783-1145

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*Physical Science Laboratory
New Mexico State University
Las Cruces, New Mexico 88003

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13. ABSTRACT (Maximum 200 words)

Net efficiencies for the dissemination of graphitic fibers are determined for two continuous processes (fibers cut as part of the dispersion process or precut). In both cases an extensive grid of passive dosimetric samplers inset with a coarser grid of time resolved aerosol density samplers provided an absolute time average dosage profile, which was integrated over space to give the total effective airborne aerosol mass. The efficiency is expressed as a ratio of the airborne mass to the total mass dispersed from the bulk. For lower dosages corresponding to a dispersed mass of less than 1 lb, use of the passive, high spatial resolution grid gave efficiencies at about the 50-percent level with no large deviations from the mean. At larger dosages, for which the total mass dispersed ranged from about 1 lb to about 50 lb, only the values obtained using coarser grid (3 x 3 instruments) were valid. In the latter case the variation in efficiency was much larger, but the average indicates at least the same level of efficiency. Dispersion rates varied from 1 lb/minute to 10 lb/minute.

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1. Background

The net efficiency for aerosol obscuration is a product of the optical efficiency and the dispersion efficiency. The efficiency of the specific optical effect (extinction or components thereof: absorption, total scattering or some angular portion of the scattered field) is defined by the effective cross sectional area of the particle for that optical effect normalized by its volume. The dispersion efficiency defines the mass proportion of the material that is made airborne in the form of independent particles from the predispersed substance.

Laboratory and field measurements (Bruce et al. 1990a, 1990b) have provided data on the optical efficiencies of graphitic independent fibers, and agreement with theory has been demonstrated. The efficiency with which fibers can be aerosolized is essentially a field task and the analysis of this report represents one facet of the 1989 and 1990 Dugway Proving Ground field measurement series (Perry et al. 1992) trial fibers.

Dispersion efficiencies relate to the system used and those of this report derive from two different approaches to the problem of converting fibers in bulk to aerosol.

Both of these techniques employ Coanda Flow (Hoerner and Borst 1975) ejectors to give impetus to the cut fibers. Air is the thrusting medium for this type of ejector and viscosity the coupling mechanism. The result is gentle but effective, breaking only a very small fraction of the particles.

Perhaps the most distinguishing feature between the two techniques of generation is that the fibers are stored in precut form for one technique and as uncut "spools" or "mats" for the other technique. In the latter case, the "tows" of several thousand fibers pass through a cutter just before entering the ejector. The cutter, a commercial design specifically developed for the graphitic fibers, most probably snaps the fibers into a tumbling mode, which helps in the separation and presents a variety of aspect angles to the ejector for further separation. In the precut mode, the fibers are stirred within a plastic container by a strong turbulent field whose overflow of air-cum-fibers is presented to the ejector. Additional descriptions of these two methods of generation are given in appendices A and B.

2. Measurements

The passive sampling grid used for these measurements is described by Bowers et al. (1990), and the interposed time resolved sampling grid is described by Bruce et al. (1990a). In brief, coarse weave (bridal veil) samplers were distributed every several meters well beyond the width and height of the clouds in a plane perpendicular to the wind direction. This grid was located 50 to 70 m from the system of generation. We have assumed for this study that those fibers passing through the 50- to 70-m array of samplers were, in effect, airborne. In support of this, a composite distribution of fibers between bundles (nonseparated groups of fibers) for a number of experiments

is shown in figure 1. This total percentage of multiples is quite small. The total measured optical efficiency is also almost the same as if there were no multiples, and the definition is quite rigorous.

The interposed grid of time resolved instruments supplied closely correlated absolute values for various quantities proportional to the aerosol densities in a much smaller region within the same plane. The consistency and accuracies of the time integrated results from these measurements provided a strong basis for the normalizing factors for the dosage profiles of the passive grid.

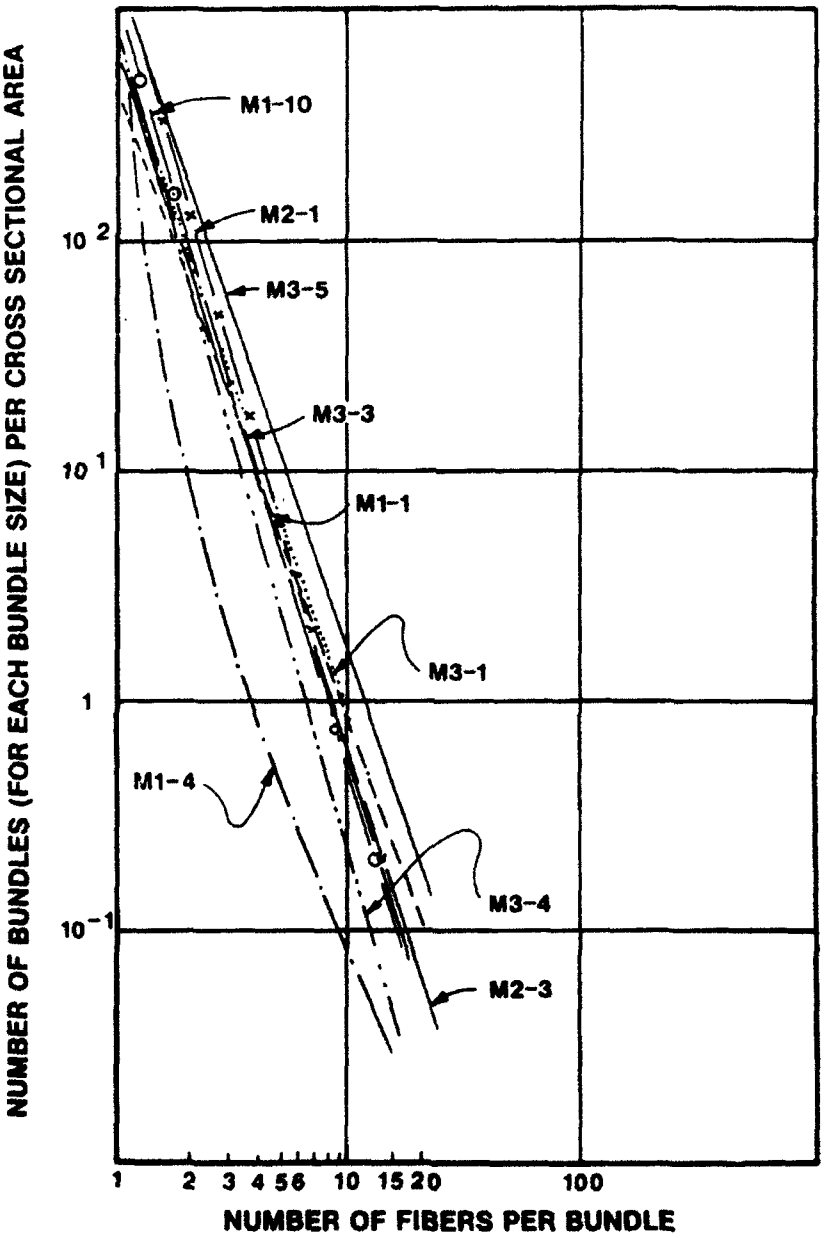

Figure 1. Distribution of fibers between bundles, field trials of 1990.

3. Results

Several conditions or restrictions on the various types of measurements limited the number of experimental trails available for analysis. For example, trials were examined to assure that the cloud profile was not sufficiently far off-center that the normalizing densities measured by the active grid would be in regions of steep slope (leading to potentially large errors), that the passive filters were not heavily loaded with fibers (causing them to become aerodynamic barriers, again leading to large errors), that all types of necessary information were available, and that no anomalies existed that could invalidate the analysis.

As a result of this filtration scheme, only five experimental trials met the strictest requirements: two for the one generation technique and three for the other. Another several permitted a less accurate type of analysis involving not the entire passive grid but a far less extensive grid of nine nephelometers (time resolved density measurements). For the latter measurements (which function well even when the average densities are very high and therefore add trials), best judgment density profiles were fit to the sparse nephelometer data. The basis for the form of the density profile was strongly aided by the valid passive profile data. Error limits here will be much broader, but the mean value is quite near that of the more precise determination.

The results of the more precise analysis are listed in table 1 by type of generator. An example is given in appendix C. The efficiencies determined in this way do not vary greatly between trials or even between the two forms of generation. Clearly it would be better to have additional trials to bolster these numbers, but such trials are not available. The second category of measurements, as given in table 2, adds information, albeit with much less accuracy.

4. Summary

Data were selected by means of several very basic a-priori requirements. From a large pool of available trials (more than 60), each requirement trimmed the number by its own fraction; and the final number available was about 1/5 of the total number available. Nevertheless, the remaining data make a clear statement. The efficiencies determined from the selected trials are fairly consistently equal to or greater than 50 percent and are not significantly different for the two approaches to preparation for dispersal, that is, fresh cut or precut. An additional and important fact is that only a small fraction of the fibers is fragmented in the process of dissemination. Still another is that the airborne fibers are separated by these techniques into "singles" to a very high degree of efficiency.

The efficiencies obtained from the coarse grid (nine nephelometers) were much less precise than those of the much more closely spaced passive filters (bridal veil material) but allowed measurements at the highest densities and dosages employed.

Table 1. Fiber Dispersion Efficiencies

Computed using fine grain 2-D array of passive dosimetric samplers

Trail number	Airborne mass/ Total dispersed mass (lb/lb)	Percentage
	(cut-as-dispersed)	
1 (DPG89, M1-2)	0.244 / 0.50	49
2 (DPG89, M1-3)	0.302 / 0.63	48
3 (DPG89, M2-1)*	0.29 / 0.44	66
	(precut)	
4 (DPG90, M2-1)	0.360 / 0.80	45
5 (DPG90, M1-2)	0.228 / 0.50	46
6 (DPG90, M2-2)**	0.027 / 0.80	---

*off-center
**low of center

Table 2. Fiber Dispersion Efficiencies

Computed using data of coarse grain (9) nephelometer grid

Trail number	Airborne mass/ Total dispersed mass (lb/lb)	Percentage
	(cut-as-dispersed)	
1 (DPG89, M1-1)	45 / 47.5	95
2 (DPG89, M3-3)	5.4 / 5.7	95
3 (DPG89, M3-2)	0.40 / 1.30	31
4 (DPG89, M2-3)	13 / 19.4	66
	(precut)	
5 (DPG90, M1-5)	4.9 / 10.2	49

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Appendix A. Cutter for Fibrous Material

The experimental millimeter wave obscurant generator is based on a fiber chopper. Additional components include a coanda flow ejector, a turbine engine and a supply of material.

The obscurant material, which is usually graphite although others have been used, comes from the factory in multiple-strand ropes, called tows, wound on spools. The number of fibers per tow can vary from 1,000 to 48,000, with 12,000 being the most common. A recent packaging concept ties from 10 to 30 of these tows together into a flat belt. This provides a variable flow rate and trouble-free storage and allows the large amounts of material to be fed into the cutter.

The cutter consists of two rollers in contact, one containing the cutting blades at fixed spacing (typically 1/8 in) and a second platen roll covered with a rubber or polymer sleeve. The platen roll is motor driven and the two rollers are held together with air pressure sufficient to force the blades through the belt of material, producing fibers of a discrete length. The fiber length can be varied by changing the blade spacing. The motor is variable speed allowing fiber belt speeds of from 0 to 12 ft/s. Proper selection of belt speed and belt size can produce throughputs of from 0 to 10 lb/min.

The coanda flow ejector consists of a short cylindrical shell with a high-speed air sheath (generated by air pressure expelled axially at the inside edge of the cylindrical shell). Momentum is then transferred to air within the cylindrical shell. The coanda flow device can thus be used to produce an air flow without mechanical interference and within which shear flow can be carefully controlled.

The coanda flow ejector separates then disseminates the fibers by accelerating them to speeds up to 1000 ft/s. In addition, it amplifies the air. That is, for every pound of bleed air from the turbine, it induces about 5 lb of ambient air. This quickly dilutes the fiber concentration and helps the fibers to remain airborne. The ejector provides one other function. Due to the velocity gradient, it provides shear that helps break up the bundles of fibers coming out of the cutter.

Appendix B. Aerosolizer for Precut Fibers

During the 1990 Dugway Proving Ground field trails a fluidized bed and ejector was used to disseminate prechoppped fibers.

The aerosolizer was plexiglass tube 10 in in diameter and 4 ft high with a combination of ejectors attached to the outlet. The aerosolizer had a capacity of about 10 lb of fibers. A low volume of air was fed through a sintered metal floor to fluidize the material. A vacuum was created by the ejector to draw the fibers out of this fluidizer "bed."

Two ejectors in series were used during this test. The first was designed for separation of the fiber bundles. It has an aerodynamic obstruction placed in its throat to force the bundles of fibers into the high shear area along the ejector walls. The fibers then passed through the projection ejector which imparted a high velocity on them and mixed them with dilution air, producing the obscurant cloud.

Appendix C. Sample Mass Calculation

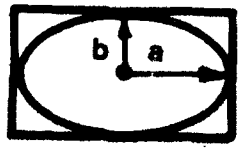
DPG 89, M1-2

Determining the efficiency of dispersion

Data from the DPG two-dimensional array passive sampling grid were used for the density contours of the net cloud as the cloud passed the 50 to 70 m sampling plane. This is not possible for many of the trials since the passive samplers were saturated and no longer giving linear results. In the remaining cases we had to rely on the 9-nephelometer array and then to use analytic fits to supplement the scarce data. Naturally, the latter cases are much more precise. This trial is one of those for which we have the total set of data. In both cases, the density profiles are calibrated in the center of the grid by the extensive set of density-related measurements located there, at 50 to 70 m.

Point-to-point connection (not analytic contours) were used to fit the density profiles as shown in figures C-1 and C-2. Then, since this two-dimensional model is in terms of sloped planes, the perpendicular profile is in each case a rectangle. This geometrical inaccuracy is corrected by making these planes into ellipses. The conversion is always the same, that is,

Area = π a b where (a) and (b) are the two half-magnitudes (of the cloud cross sectional dimensions).



For a rectangle, the area is 4 a b so the ratio is $\pi/4$ of the rectangle for each perpendicular plane. Thus the net cloud mass is given by:

($\pi/4$) (distance across) (vertical distance) (areal density) where the areal density is (dosage) (average wind speed). The dosage is given by $\int \rho(t)\, dt$ in (g/m^3) (m/s).

For the trial, M1-2, we have:

($\pi/4$) (15.2 m) (10.5 m) (5.2 m/s) (0.17 g/m^3) = 111 g = 0.244 lb

Disseminated: 0.50 lb for an efficiency of 49 percent.

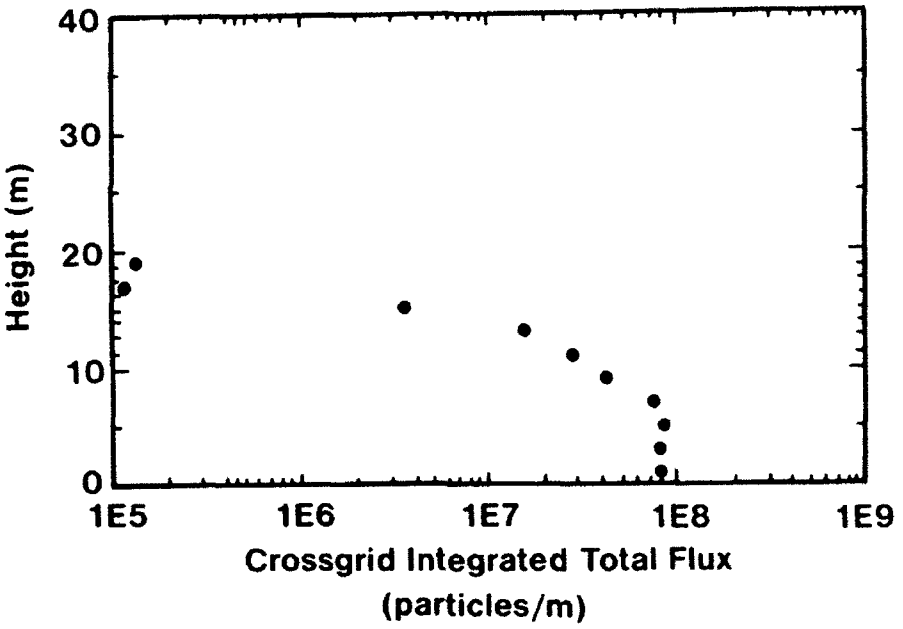


Figure C-1. Mean vertical aerosol dosage profile.

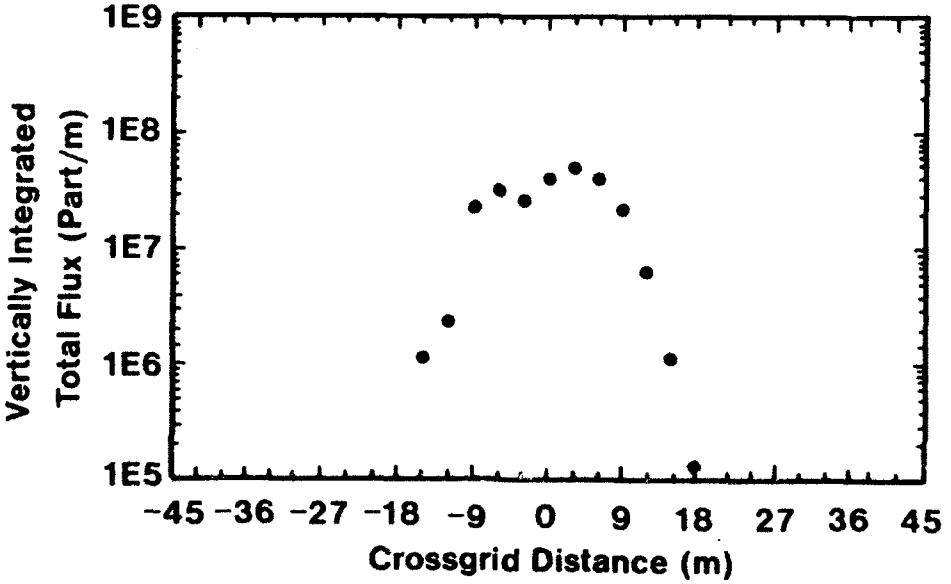


Figure C-2. Mean horizontal aerosol dosage profile.

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