Generation of Particle Clouds by means of Pressurized Gas and Gas Generators

Helmut Schneider, Norbert Eisenreich
Fraunhofer Institut für Chemische Technologie
76327 Pfinztal, Germany
hs@ict.fhg.de

Abstract

The controlled release and dispersion of µm sized particles into the surrounding atmosphere is of interest in several research projects at ICT. In each case a particle cloud with special geometry and particle concentration should be generated within a short time scale of a few milliseconds to about 100 ms. The basic idea is a realization by means of gas generators. In this context, tests with pressurized gas on a large scale and on a small scale were performed. The modeling of the propagation of the cloud with respect to geometry and volume can be achieved by simple assumptions.

1. Introduction

The knowledge on how to release and disperse small particles on a short time scale is important for several applications, which are dealt with at ICT: further development of fuel air explosives systems for conventional application /1/ and eventually as a defence system against B- and C- weapons /2/, non-lethal weapons systems, and in the field of safety technology the investigation of dust explosions and the development of fire extinguishing systems. The objective is the generation of a particle cloud within some milliseconds to about 100 ms with special geometry and particle concentration within the cloud. This can probably be best achieved by use of gas generators. These can be „tailored“ for the special application with respect to for example burning velocity, -temperature and gas output; together with an appropriate design of the mechanical construction the generation of a well-defined cloud seems to be possible. In this paper the results of dispersal tests with pressurized gas are presented.

2. Experimental

The components of the whole system – gas generator, mechanical construction, properties and amount of dispersed substance must carefully be matched with each other. Since there will be done a large number of tests to clarify these correlations, tests should be made on a small scale; however, since the dispersal of a large amount of mass may be different and since the explosion of a particle cloud with energetic particles can be evaluated only for minimum cloud sizes, tests on a realistic scale are also necessary. Therefore tests with two different sized devices were done. In Fig.1 the large system is shown. It consists of a tube system with volumes of ca 20 l and 40 l. At the front side the dust container is mounted. Between the tube filled with pressurised gas and the container a bursting disc and an „adapter“ is installed, matching the tube to the square sized cross section of the container. The dust material consisted of 120 μm KCl particles. In table 1 the test parameters and test results are listed. The test parameters and results of the small system are listed in table 2. The volumes, the height of the dust container and the masses were reduced by a factor of 4. For both systems the times for the pressure drop to ambient pressure were the same and were between 100 and 200 ms. The dispersal of the particles was recorded with a high speed video camera with 1000 frames/sec perpendicularly to the direction of propagation..

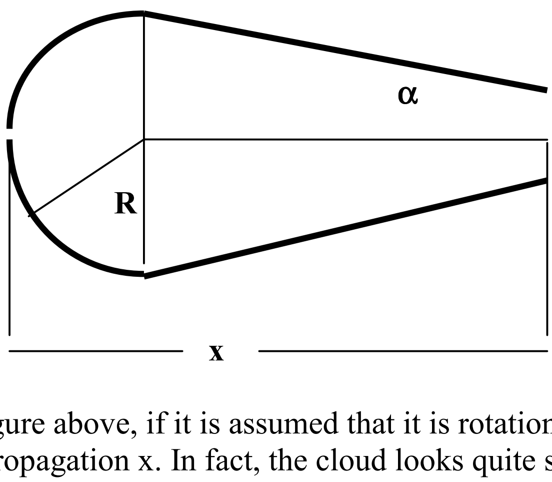
3. Results

The propagation of the particle cloud was analysed with respect to the distance of the front of the cloud as a function of time. It was assumed that the cloud was decelerated like a solid body in a flow. Therefore the data were fitted with

$$x(t) = U/D \{1 - \exp(-Dt)\} \qquad (1)$$

The result is shown in Fig.2. The values of the starting velocity U and of the coefficent D are listed in tables 1 und 2. A comparison of the data shows that the bursting or initial pressure of the systems has a significant effect on cloud propagation, i.e.. the front of the cloud reaches a certain distance much faster if the initial pressure is higher. The effect of different initial volumes is very small. The same holds for different masses, apart from the fact that larger masses are less accelerated at the beginning of the propagation. This observations are reflected in the calculated values of U.
Other important parameters are the geometry and the volume of the cloud. Therefore the volume of the cloud was estimated at different times of the propagation progress by means of high speed film records. The data were fitted with the relation (Fig.2)

$$V = \pi/3 \{2 + k^{-1}\}\{k/(1+k)\}^3 \; x^3 \qquad (2)$$
$$k = \tan\alpha; \qquad \tan\alpha = R/(x - R)$$



This is the volume of the figure above, if it is assumed that it is rotational symmetric with respect to the direction of propagation x. In fact, the cloud looks quite similar after it had propagated some distance from the outlet. The values of the (half) angle α resulting from the fit are listed in tables 1 and 2. Theoretically in the „main region“ of a stationary jet of an incompressible fluid $\alpha \approx 12.5^0$ (/3/). This corresponds very well with the data of table 1(large system). For the small system the values generally are lower; the cause for that is not yet clear. If it is assumed that the particles are homogeneously distributed within the cloud and since the dispersed mass is known, a mean particle concentration within the cloud can be calculated from the results.

4. Literature

1. N. Eisenreich, H. Schneider
   Entwicklungsmöglichkeiten künftiger Fuel Air Explosives Systeme
   Int. Annual Conference, ICT, Karlsruhe (1999)

2. N. Eisenreich, H. Schneider, K.D. Thiel
   Anti-BC-Wolken-Wirkkonzepte
   Wehrtechnisches Symposium „Wirkung und Schutz, Explosivstoffe“
   Bundesakademie für Wehrverwaltung und Wehrtechnik, Mannheim (2000)

3. G.N. Abramovich
   The theory of turbulent jets
   MIT Press, Massachusetts (1963)

Fig.1: Apparatus for the dispersal of particles with pressurized gas

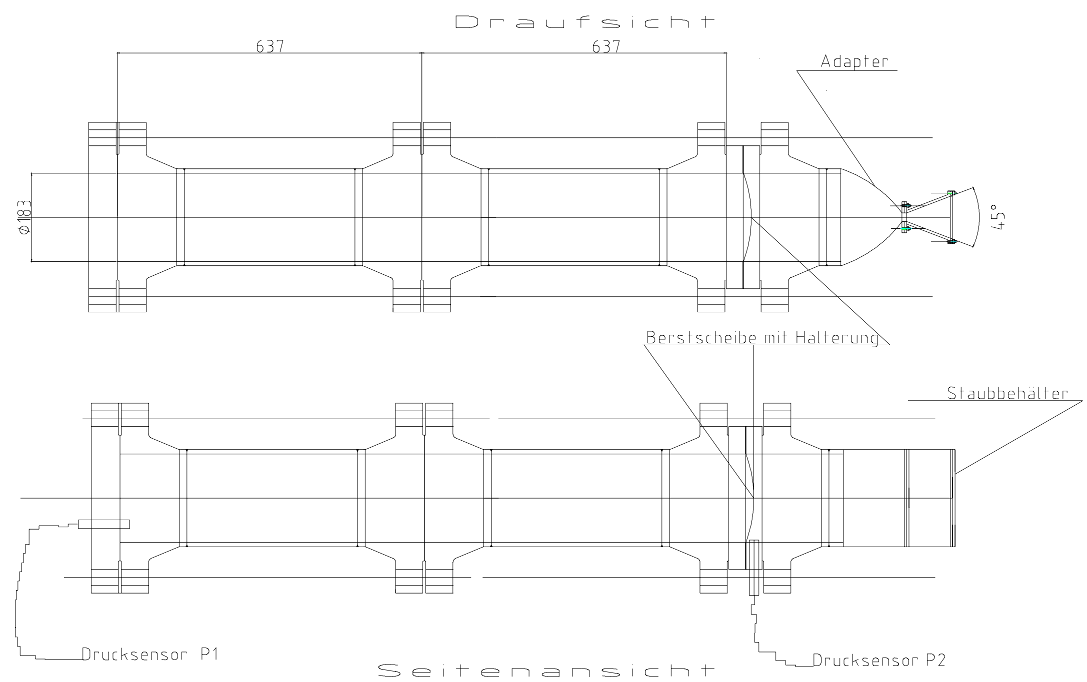


Table 1: Test parameters and results (large system)

Test No.	10	11	12	13	14	15	17	18
Volume (liters) of pressurized gas	35,2	35,2	35,2	18,5	18,5	18,5	18,5	35,2
Pressure (MPa) of Pressurized gas	4,87	9,12	4,86	4,88	4,87	9,31	9,02	9,43
Mass (kg) of dispersed particles	1,26	1,26	2,52	2,52	1,26	1,26	2,52	2,52
Starting velocity (m/s) of jet flow (calculated)	200 ±9	218 ±7	154 ±14	148 ±10	201 ±8	222 ±13	183 ±11	209 ±10
Coefficient D (sec^{-1})	20,9 ±0,7	18,8 ±0,4	16,2 ±1,0	17,3 ±0,8	25,4 ±0,7	21,6 ±0,9	20,7 ±0,8	18,8 ±0,6
Half angle α (degrees) of jet flow (calculated)	9,4 ±0,3	10,1 ±0,5	11,2 ±0,6	10,8 ±0,8	12,2 ±0,7	13,1 ±0,6	9,7 ±0,4	11,3 ±0,3

Table 2: Test parameters and results (small system)

Test No.	20	21	22	23	24	25	26	27
Volume (liters) of pressurized gas	4,6	4,6	4,6	4,6	8,8	8,8	8,8	8,8
Pressure (MPa) of Pressurized gas	4,95	10,09	9,45	4,93	5,19	4,70	9,57	9,84
Mass (kg) of dispersed particles	0,32	0,32	0,64	0,64	0,64	0,32	0,32	0,64
Starting velocity (m/s) of jet flow (calculated)	129 ±10	157 ±12	154 ±7	96 ±5	123 ±6	110 ±7	143 ±15	156 ±10
Coefficient D (sec^{-1})	23,8 ±1,3	25,2 ±1,4	23,0 ±0,7	13,9 ±0,4	16,8 ±0,5	15,9 ±0,7	19,8 ±1,4	18,9 ±0,8
Half angle α (degrees) of jet flow (calculated)	10,0 ±0,3	12,3 ±0,4	9,4 ±0,2	8,2 ±0,3	9,0 ±0,3	9,9 ±0,3	10,5 ±0,3	7,6 ±0,2

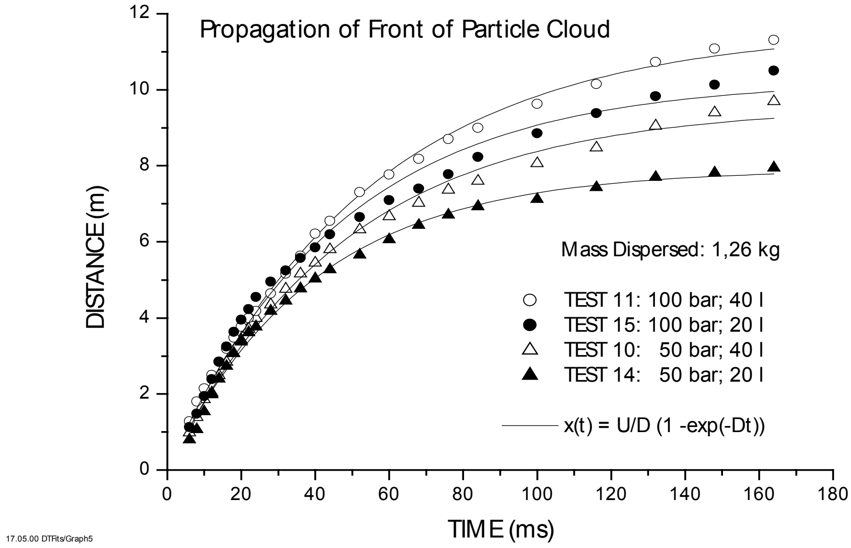


Fig.2: Propagation of the front of the particle cloud

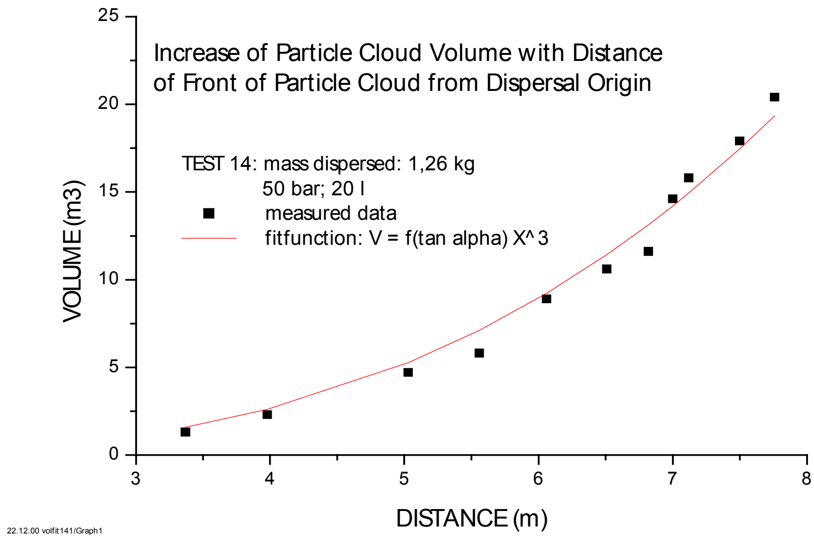


Fig.3: Increase of particle cloud volume with distance of front of particle cloud from dispersal origin