2630

NT-87-01-3

AIVC 2164

2630

TEST VENTILATION WITH SMOKE, BUBBLES, AND BALLOONS

P.L. Pickering A.L. Cucchiara M. Gonzales J.L. McAtee

ABSTRACT

The behavior of smoke, bubbles, and helium-filled balloons was videotaped to demonstrate the mixing of air in the plutonium chemistry laboratories a plutonium facility. The air-distribution patterns, as indicated by each method, were compared. Helium-filled balloons proved more useful than bubbles or smoke in the visualization of airflow patterns. The replay of various segments of the videotape proved useful in evaluating the different techniques and in identifying airflow trends responsible for air mixing.

INTRODUCTION

This report describes and compares three methods used to visually demonstrate the airflow patterns within a plutonium processing laboratory. For this study, smoke, bubbles, and helium-filled balloons were released into a laboratory and videotaped to provide a visualization and understanding of the airflow patterns in the work areas.

The TA-55 Plutonium Facility (Figure 1) located at Los Alamos, New Mexico, was designed according to specifications given in Chapter XXI of DOE Order 6430.1, "General Design Criteria Manual." The facility has been operating since 1978 and functions as a research and development laboratory handling kilogram quantities of plutonium.

A radioactive transuranic heavy metal, plutonium (Pu) and several of its daughter products decay by alpha particle emission (Gollnick 1983). An alpha particle is a relatively large, highly positively charged nuclear particle, which, due to its size and limited range in air (3-5 cm) and its negligible skin-penetrating power, is primarily an internal hazard (Gollnick 1983).

A major pathway for internal deposition is through inhalation. Therefore, the primary radiation protection concern for this facility is to monitor for airborne plutonium, to alert laboratory workers to its presence within the laboratories, and to remove it rapidly in the event of an airborne release.

The facility's ventilation system is designed to remove airborne plutonium from process laboratories by mixing and removing air at a ventilation change rate of seven room-air changes per hour. Group A diffusers, which discharge air horizontally, are located in the ceiling of each laboratory and supply recirculated, HEPA-filtered air (Figure 2). Ten percent makeup air flows through the doorways of the laboratories from the corridors. Due to heat-producing equipment housed within the laboratories, the ventilation system functions year-round in a cooling mode, resulting in the theoretical air distribution illustrated in Figure 3 (ASHRAE 1985). This is important from a health physics standpoint, because one way to minimize worker exposure to airborne plutonium is to thoroughly mix and remove laboratory air. If the system were to operate in the heating mode (Figure 4) (ASHRAE 1985), the resulting stagnant zone would inhibit this process. The cooling mode also creates health physics problems, however,

P. L. Pickering, Health Protection Technician; A. L. Cucchiara, Staff Health Physicist; J. L. McAtee, Deputy Group Leader; M. Gonzales, Staff Health Physicist; Chemistry Health Protection, Los Alamos National Laboratory, Los Alamos, NM.

in that airborne plutonium, which would ordinarily settle to the floor, could become resuspended and, thus, increase the potential of personnel exposure in the room. Consequently, airflow patterns that result in stagnant zones or in the resuspension of plutonium particles are undesirable from the health physicist's point of view.

Identification of actual airflow patterns within the working environment is extremely valuable to the health physicist. Knowledge of this information might reveal existing undesirable airflow patterns, such as stagnant areas or areas where plutonium is likely to become resuspended or recirculated, and might indicate room clearance rates. As a result of this knowledge, the room air-ventilation system could be improved or new systems designed to minimize undesirable airflow patterns. By minimizing these undesirable patterns, potential exposure of personnel to airborne plutonium could be reduced.

TESTING WITH SMOKE, BUBBLES, AND BALLOONS

The laboratory evaluated in the study measures 30 x 60 x 15 ft (27000 ft^3) and contains four rows of gloveboxes 7 ft high. Approximately 20 persons are engaged in plutonium scrap recovery and health physics monitoring in this area. Four ceiling diffusers each supply air at a rate of approximately 1280 cfm. The adjacent corridor has positive air pressure with respect to the laboratory. Ten percent makeup air, which is HEPA- filtered once, is supplied to the laboratory through the corridor doors. Ninety percent of the room air is recirculated through two sets of HEPA filters; approximately 1000 cfm is exhausted through each of the five floor registers.

To visualize the effects of the ventilation system on room air mixing, we released smoke, bubbles, and helium-filled balloons at various points around the room and captured their behavior on videotape. The following equipment was involved in the test procedure.

1. A multihead bubble generator (Figure 5), which produces helium-filled, neutrally buoyant bubbles of controlled, uniform size, 1/16 - 1/4 in in diameter.

2. Smoke bombs (Figure 6) colored white, red, and green.

3. Helium-filled balloons weighted with tape to maintain neutral buoyancy.

4. A color video camera with single tube and zoom lens and a portable VHS recorder.

The helium-filled soap bubbles were released at a rate of 10 to 50 bubbles per second and tracked for approximately 1 hour. Taping was done throughout the room with particular emphasis on the behavior around the ceiling diffuser.

The smoke bombs were lighted and, again, total room dispersion was recorded. Additionally, several smoke bombs were released near the floor exhaust vents to graphically demonstrate the air removal at this point.

The helium-filled balloons were released from stationary positions at various points around the room. Particular attention was paid to the effects of the diffuser, to the exhaust register, and to the 10% makeup air flowing in from the corridor door. The helium-filled balloons proved the most effective of the three methods for indicating the dynamic airflow patterns within the laboratory and relating them to the ventilation design characteristics. The helium-filled bubbles were too small, too diffuse, and too numerous to satisfactorily follow upon their release. Further, they were released with initial momentum in the direction of the release nozzle and their natural buoyancy confounded the interpretation of airflow patterns. The smoke bombs displayed all of these same limiting characteristics, including the inability to turn the release on and off at will. While both of these methods indicated the gross airflow patterns in the laboratory, the level of detail that could be gleaned from observation and videotaping was very limited.

The helium-filled balloons overcame all of the above-noted limitations and proved to be an extremely useful method for characterizing airflow patterns originating at any given point in the lab. They were large enough to follow easily, only a single balloon needed to be watched, and the balloons could be viewed for relatively long periods of time as they followed the air currents throughout the work area. By releasing the balloons at various locations, the overall airflow patterns were easily determined.

Initially, the balloon method was tried using a single balloon filled with helium. However, we discovered that helium diffusion through the rubber membrane quickly negated the neutral buoyancy. Therefore, one balloon was placed inside another before helium was added. After a little practice, we determined the appropriate size of the balloon needed to give it a slight positive buoyancy. Then, by applying small pieces of masking tape to the balloon surface, we could weight the balloon to a neutral point where it neither rose nor fell when initially released in a static environment.

While the balloons proved most effective overall in identifying air patterns in the laboratory, the bubbles provided a better indication of the room's three-dimensional airflow direction.

DISCUSSION

Possible sources of experimental error for the procedure used include performing the experiment after operating hours when the room was free of personnel whose movements would have significantly affected the motion of room air, and room furnishings and equipment, particularly the gloveboxes, both of which alter the standard room-air distribution illustrated in Figure 3.

Each of the experimental methods had certain advantages and disadvantages as listed below.

Smoke

Advantages:

- initially very visible by illustrating mass airflow pattern in its early stages
- displayed the vent exhaust flow better than the balloon

Disadvantages:

- camouflages itself
- clogs and discolors room exhaust filters
- irritates lungs of users

Bubbles

Advantages:

- size (less inertia than balloon yet easier to distinguish than smoke)
- displays overall room distribution in three dimensions

Disadvantages:

- hard to see on film
- apparent random motion interferes with actual airflow patterns followed by bubbles
- generator awkward and messy

Balloon

Advantages:

- easily observed
- best demonstration of effects of supply diffuser
- best indication of the 10% makeup air through the corridor doors
- could better follow a single increment of air

Disadvantages:

- difficult to maintain neutral buoyancy
- large size results in poor aerodynamics
- one balloon does not display a three dimensional airflow pattern

Each method provided a visual verification of some known aspect of the ventilation system. The videotape also proved to have certain advantages and disadvantages.

Advantages:

- -- provides a permanent record of air distribution
- -- the data are retrievable without experimental repetition
- -- provides detailed visual analysis through slow motion and reversal of film
- -- indicates the relationship between airflow media and particular obstructions
- -- provides visualization of previously identified actions

Disadvantages:

- -- yields a two-dimensional representation

Through our evaluation of the use of helium-filled balloons for demonstrating room airflow, we learned that the existing airflow pattern in our plutonium laboratories may be detrimental, in some aspects, for personnel safety. The ceiling diffusers tended to lift air that originated several feet above the floor and then to distribute that air across the room. In the event of an airborne release of plutonium particles, the air motion caused by the diffusers is expected to lift the particles into the air and distribute them across the room, in a manner similar to what was observed with the helium-filled balloons. This is undesirable in that personnel who are in the room but are remotely located from the origin of the release would be subject to exposure.

Several of our investigators theorized that the airflow pattern may be improved if the "clean room" concept, which is used in the semiconductor industry, were applied to our plutonium laboratories. Consequently, further study will concentrate on defining the existing airflow patterns in our plutonium laboratory by using the method of videotaping helium-filled balloons. The size of the balloons may be varied and a different fill gas used, for example, dry nitrogen. Temporary modifications to the air supply diffusers then may be initiated, to intentionally change the airflow pattern to more closely resemble the clean-room type of airflow, and then the balloon study repeated. Additionally, we anticipate the use of a second video camera to produce a three-dimensional view.

CONCLUSIONS

The experiment resulted in the formulation of the following conclusions.

1. The action of the air-handling system can be visualized through the use of smoke, bubbles, and helium-filled balloons.

2. The videotape enhances the experimental procedure by providing a permanent record for review and study.

3. The helium-filled balloons proved to be more advantageous than the smoke and bubbles.

4. Existing airflow patterns in the laboratories could expose personnel to plutonium particles in the event of an airborne release.

REFERENCES

ASHRAE. 1985. ASHRAE handbook--1985 fundamentals, pp. 32.1-32.3. Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

Gollnick, Daniel A. 1983. Basic radiation protection technology, p. 29, 322. Pacific Radiation Press.

Miller, P. L., and Nevins, R. G. 1974. "Room air distribution." ASHRAE Journal, Jan. 1974, p. 92.

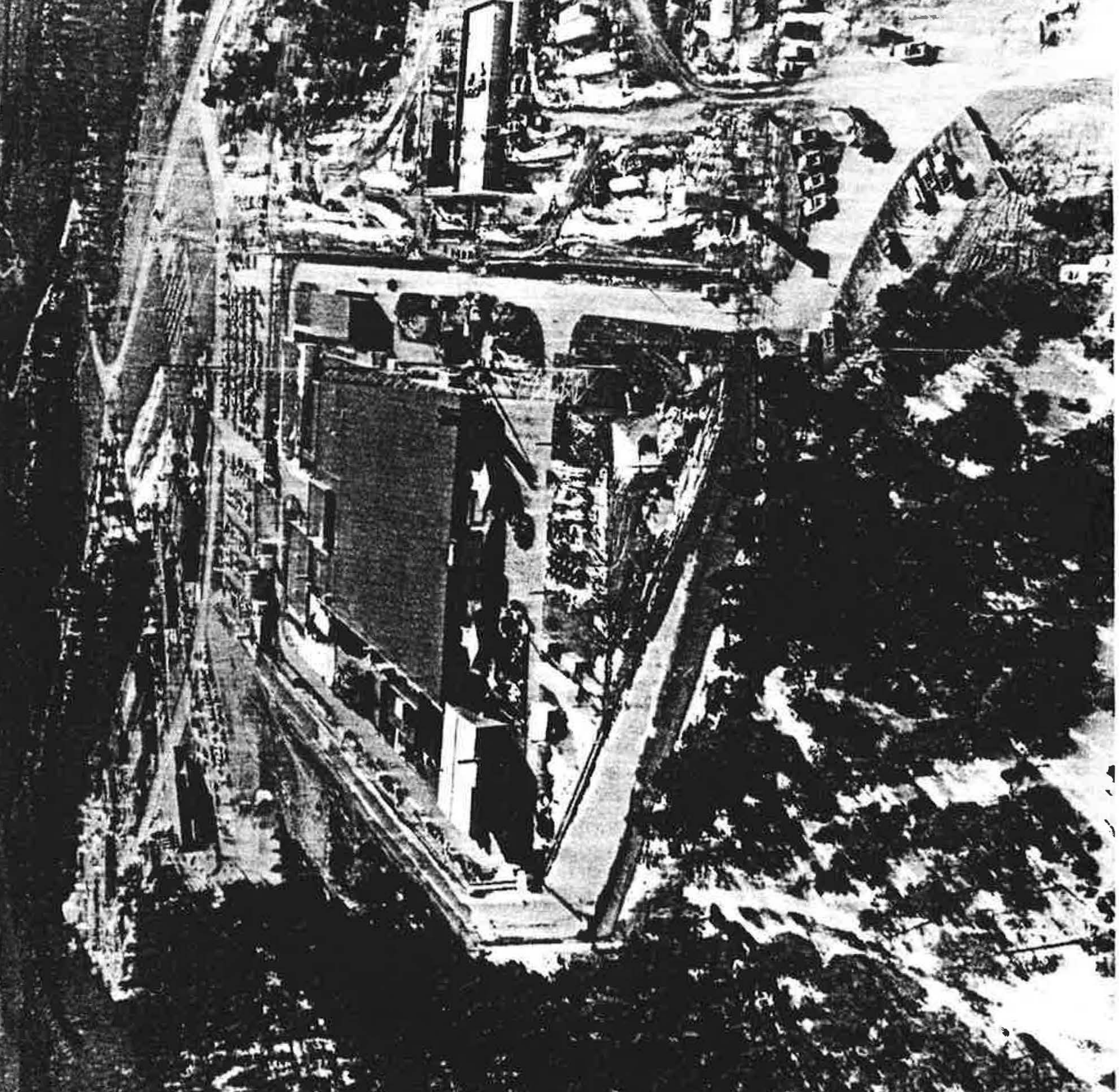

Figure 1. Aerial view of TA-55 plutonium facility

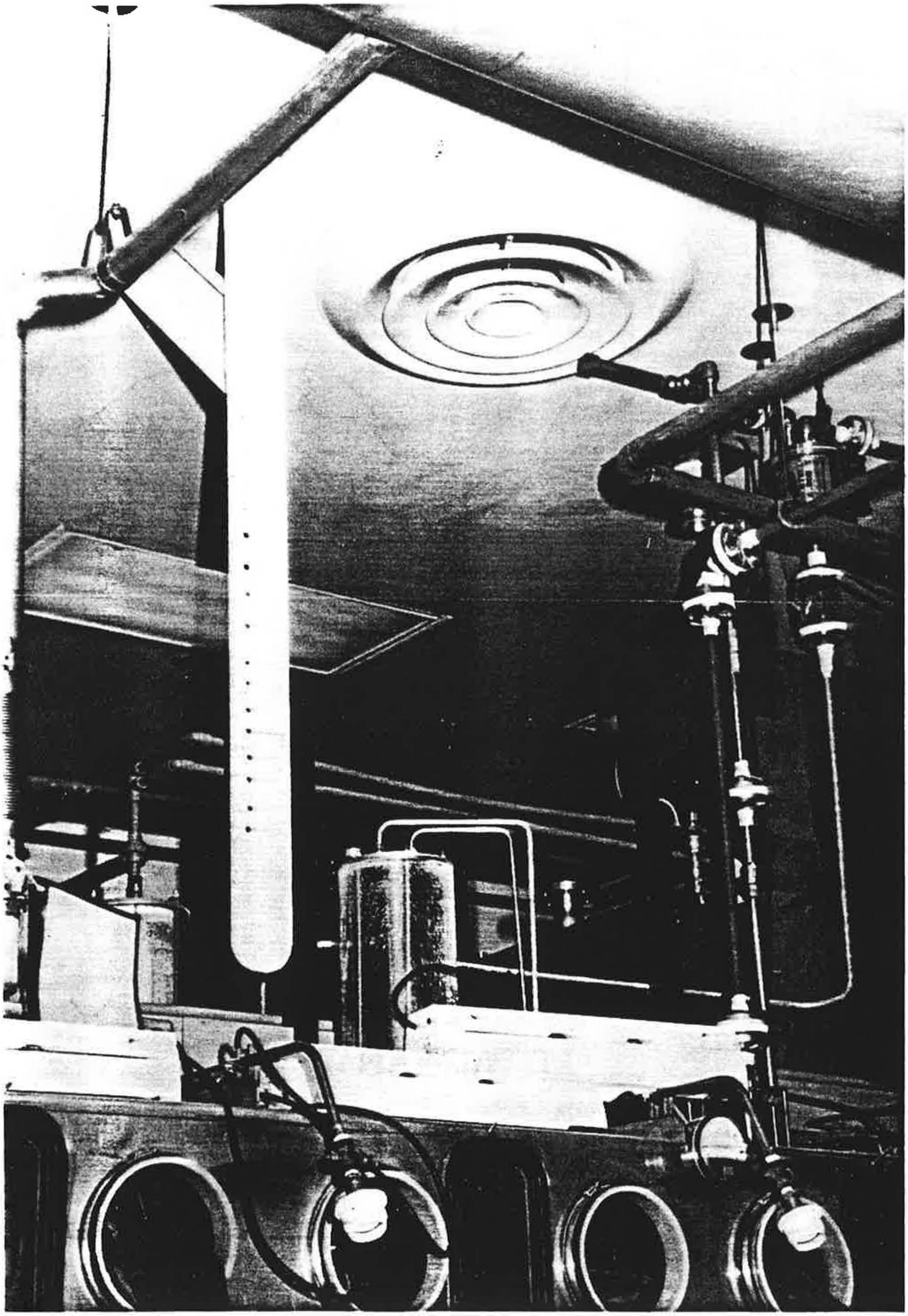

Figure 2. Group A type ceiling diffuser

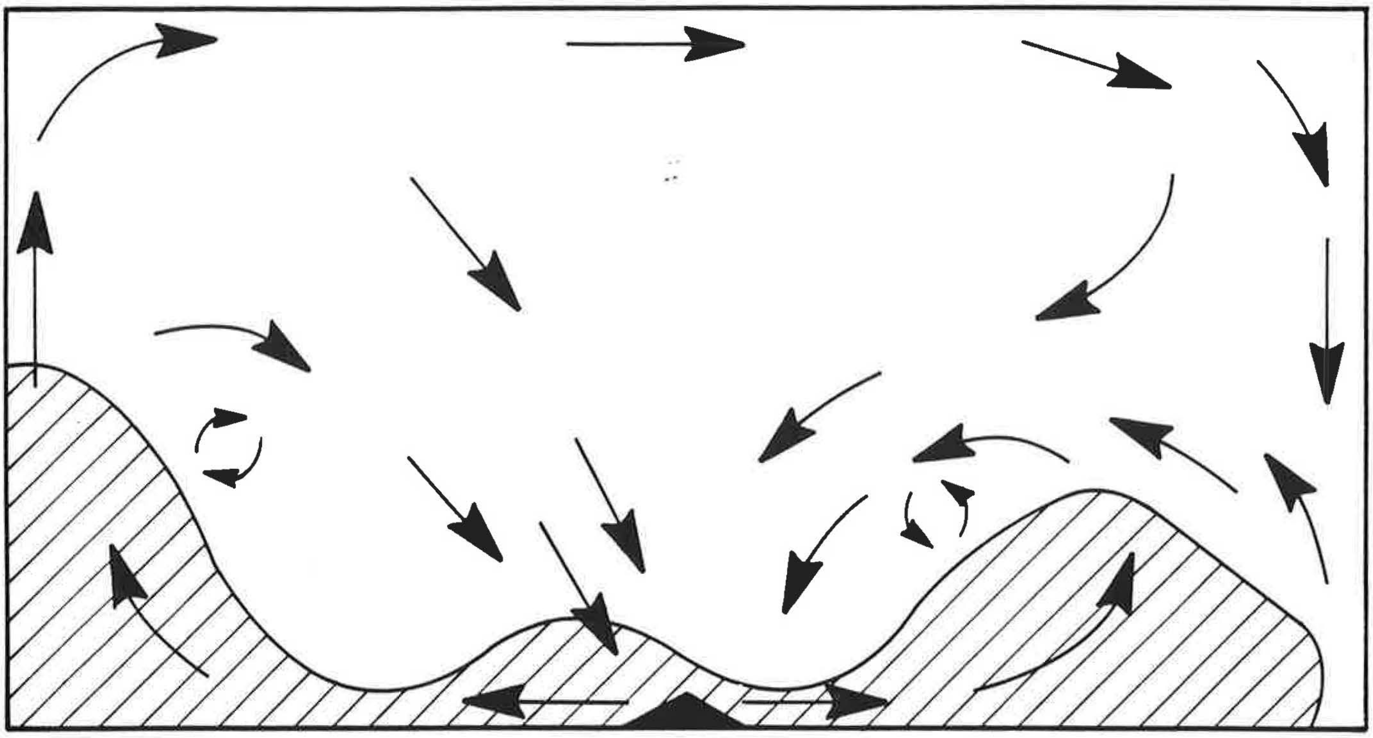

Figure 3. Air motion characteristics of group A outlets--cooling

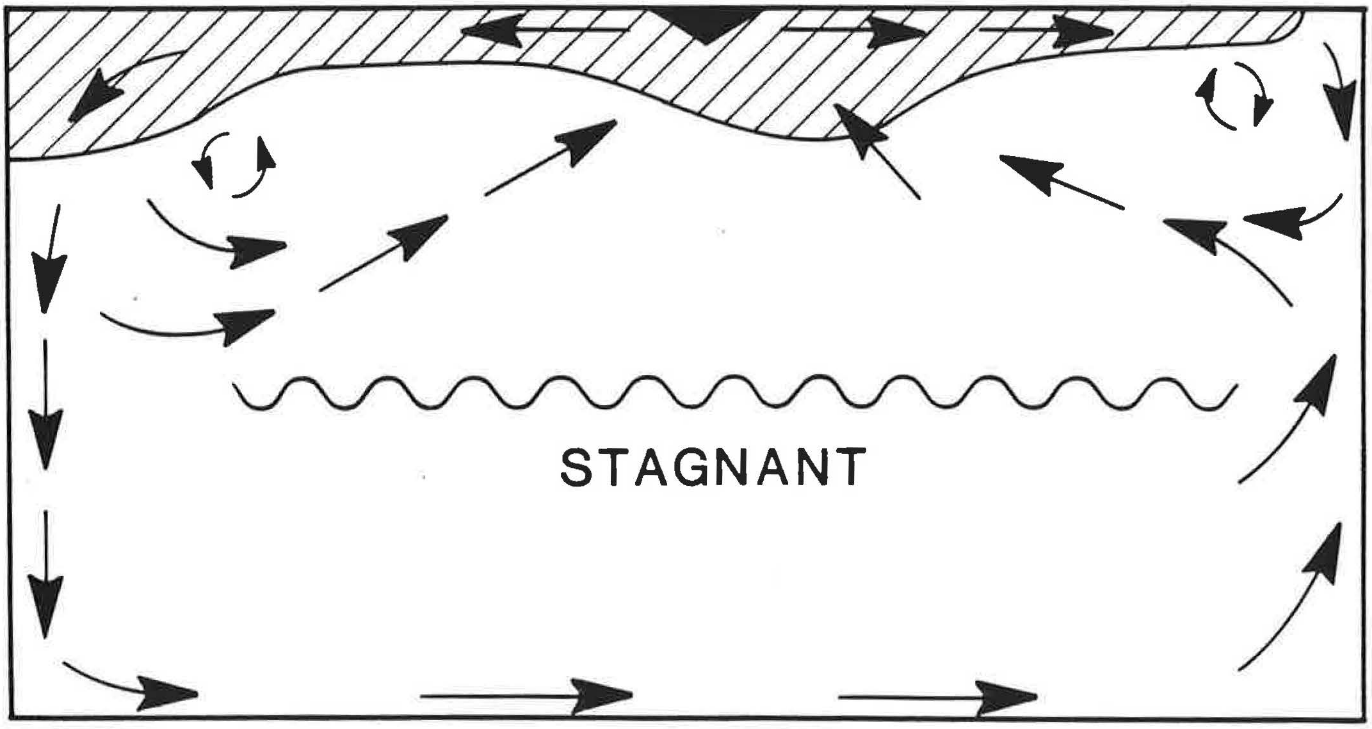

Figure 4. Air motion characteristics of group A outlets--heating

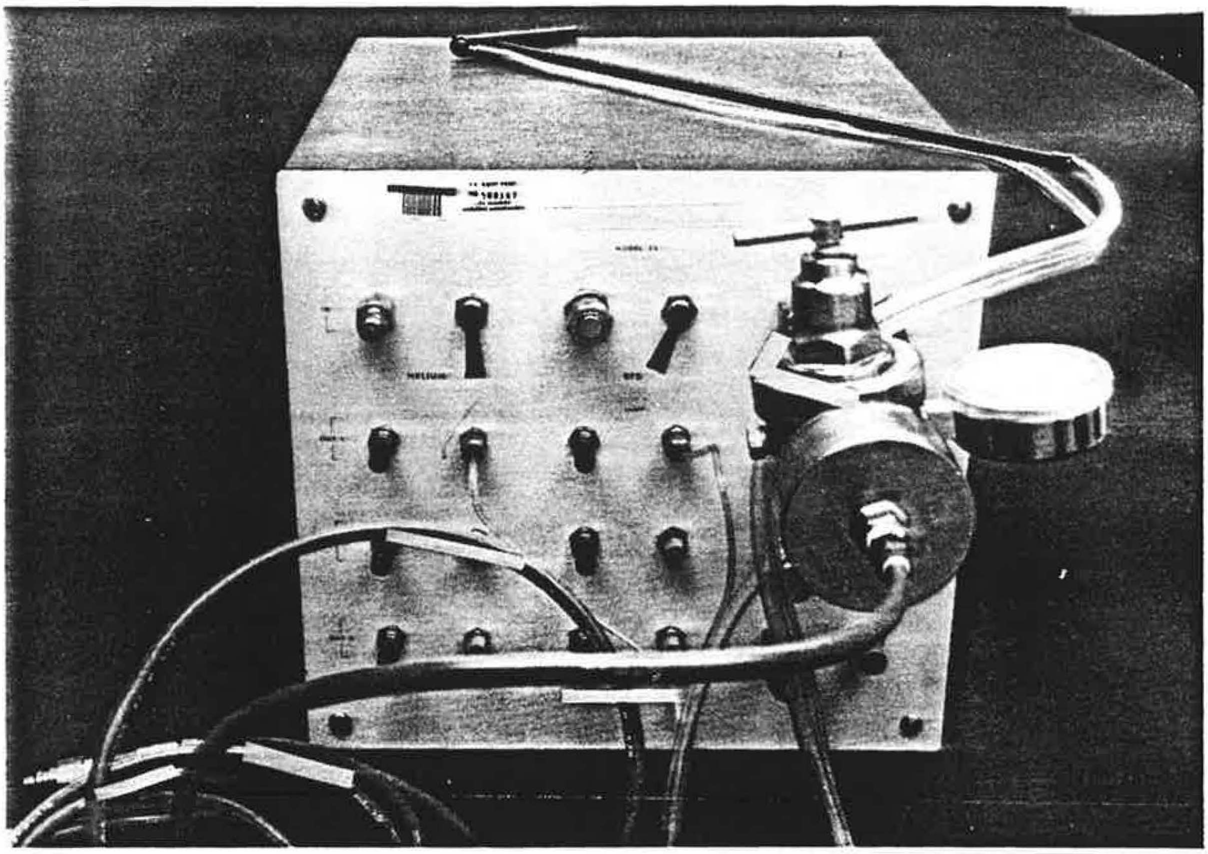

Figure 5. Multihead bubble generator

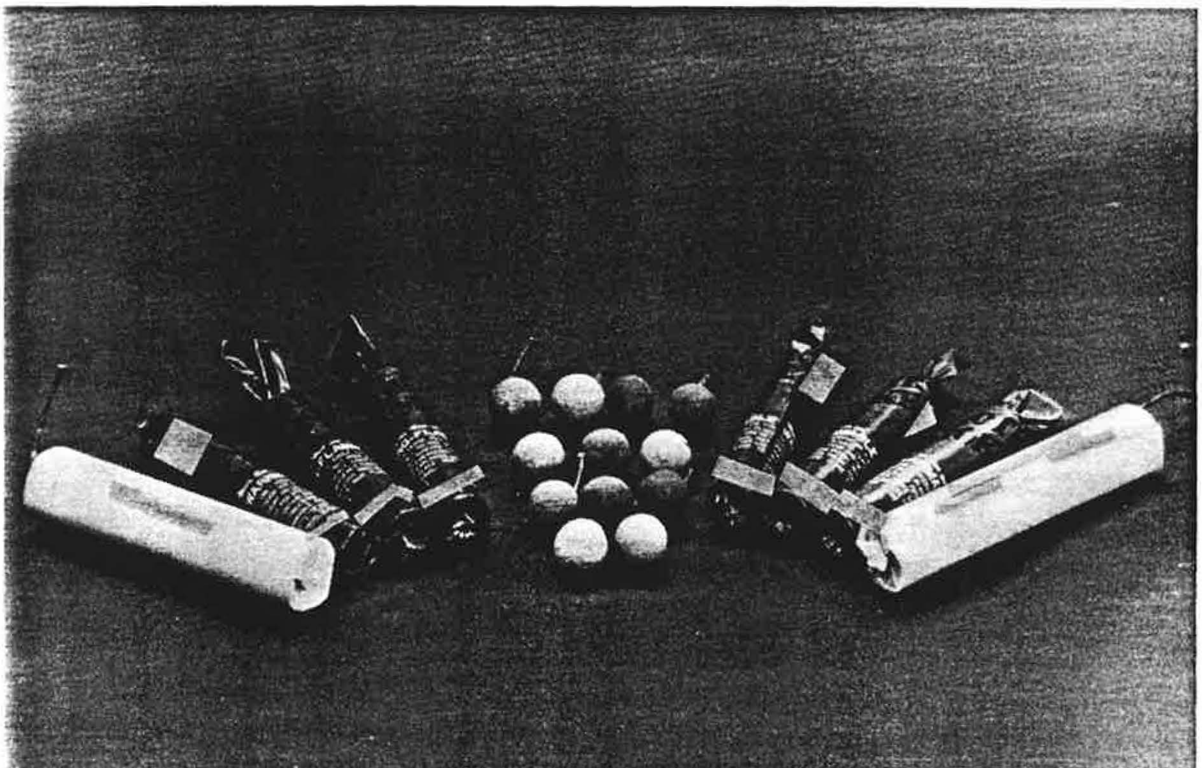

Figure 6. Smoke bombs

BIBLIOGRAPHY

Cember, H. 1983. Introduction to health physics. Pergamon Press.

Miller, P. L. 1979. "Design of Rroom air diffusion system using the air diffusion performance index (ADPI). "ASHRAE Journal, October, p. 85.

Miller, P. L., and Nevins, R. G. 1974. "Room air distribution - An ASHRAE engineering practice monograph." ASHRAE Journal, January, p. 92.