ANL/CHM/PP--76144

A New Method for Infrared Imaging of Air Currents In and Around Critical Hazard Fume Hoods

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An effective, safe real-time method of measuring and recording the efficacy of vapor containment in and around critical hazard fume hoods has been developed. An infrared camera whose response is restricted to a spectral range that overlaps a strong absorption band in a non-toxic gas is used to render real-time video images of the presence and flow of the gas. The gas, nitrous oxide, is ejected in a continuous stream in and around fume hoods that are to be certified capable of containing hazardous fumes. The principal advantage is that various scenarios of air flow displacement in and outside the hood can be easily investigated; the principal limitation is the necessity of high tracer gas concentration to obtain strong visualizations. With support from the Office of Basic Energy Sciences, Division of Chemical Sciences, U. S. Department of Energy, the technique was developed at Argonne National Laboratory by James R. McCreary and William A. Mulac of the ANL Chemistry Division and Henry Schmalz of Thermal Surveys Inc., Rockford, Illinois.

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Many regulatory orders specify the minimum distances required between fume hoods and sources of air flow such as doors, ducts and vents (e.g., United States Department of Energy Order 6430.1A (1989), p. 11-6) . To apply these regulations to existing fume hoods could (and in our case, would) be an extremely costly affair. To satisfy the intent of the regulations in the most cost effective way, we are attempting to develop an *in situ* testing procedure that will show if the present hood locations and exterior air flows are sufficient to demonstrate that the present laboratory/hood designs and placements are acceptable to the standards suggested in the order. Our approach was to expand earlier testing procedures so that we could have a visual record of the hood tested in a manner that could be rechecked whenever conditions in the hood's environment changed. A video recording of a visible vapor as it was being either contained in the hood or drawn into the hood from an external source under a series of expected (and unexpected) conditions would approach this goal. Unfortunately visualization techniques that have been used in the past are now considered too environmentally abusive to be allowed today. Neither smoke bombs, applications of titanium tetrachloride nor aqueous uranine aerosols are environmentally acceptable.

We have developed a technique that incurs no negative insults in or around the hoods to be tested. We use a non-toxic gas, which absorbs infrared energy strongly, and can be viewed in an atmosphere principally of air. The Material Safety Data Sheet (1986) of nitrous oxide, N_2O, places it in the same class as nitrogen gas, namely that its greatest health hazard is that its presence replaces oxygen in air. To visualize the air flow in and around the hoods an infrared sensing camera [AGEMA Thermovision 870 Scanner] which has a near infrared spectral response from two to five microns was modified with a narrow band pass filter that overlapped the very strong asymmetric stretching mode of N_2O, a linear gas molecule with a strong absorption band centered at 4.5 microns (Figure 1.A). With this filter the output response is significantly greater in detecting the gas, and therefor the air flow patterns. With an appropriate filter, carbon dioxide, CO_2, can also be used (Figure 1.B). The camera and the associated portable electronics equipment are shown in Figure 2. The camera has a thermoelectrically cooled detector which enhances its adaptability (in that no liquid nitrogen or other coolant that needs replenishing is needed) and a refresh rate of 25 frames per second. So that the camera can detect the presence of this gas a 2 ft by 4 ft heat curtain, with a surface temperature of ca. 129° F, was placed opposite the camera lens with the flowing gas positioned between them. The placement of equipment as shown allowed an unrestricted view, in real time, of the flow patterns of the N_2O leaving the J-tube which was aimed at the mannikin's chest. At the right of the hood can be seen the nitrous oxide tanks, flow meter and tubing which comprise the gas delivery system. To conform with American Society of Heating, Refrigerating, and Air-Conditioning Engineers standards gas flow was set at 4 Lpm or 8 Lpm in typical runs. The mannikin is fitted with a sniffer tube located near the mouth region; gas collected from this tube is drawn by a pulse pump to the collection bag on the belt.

The real-time monitor (left) and the VHS (the signal which is archived - right) screens show that the gas being discharged (indicated by the red/yellow/white colors in the lower third of the viewing area) is below the tip of the sniffer tube (seen about two-thirds the way up on the left side). The color bar running vertically to the right of the gas image was roughly calibrated and represented a range of 2 to 15% v/v (N_2O/air) in a pathlength of one cm.

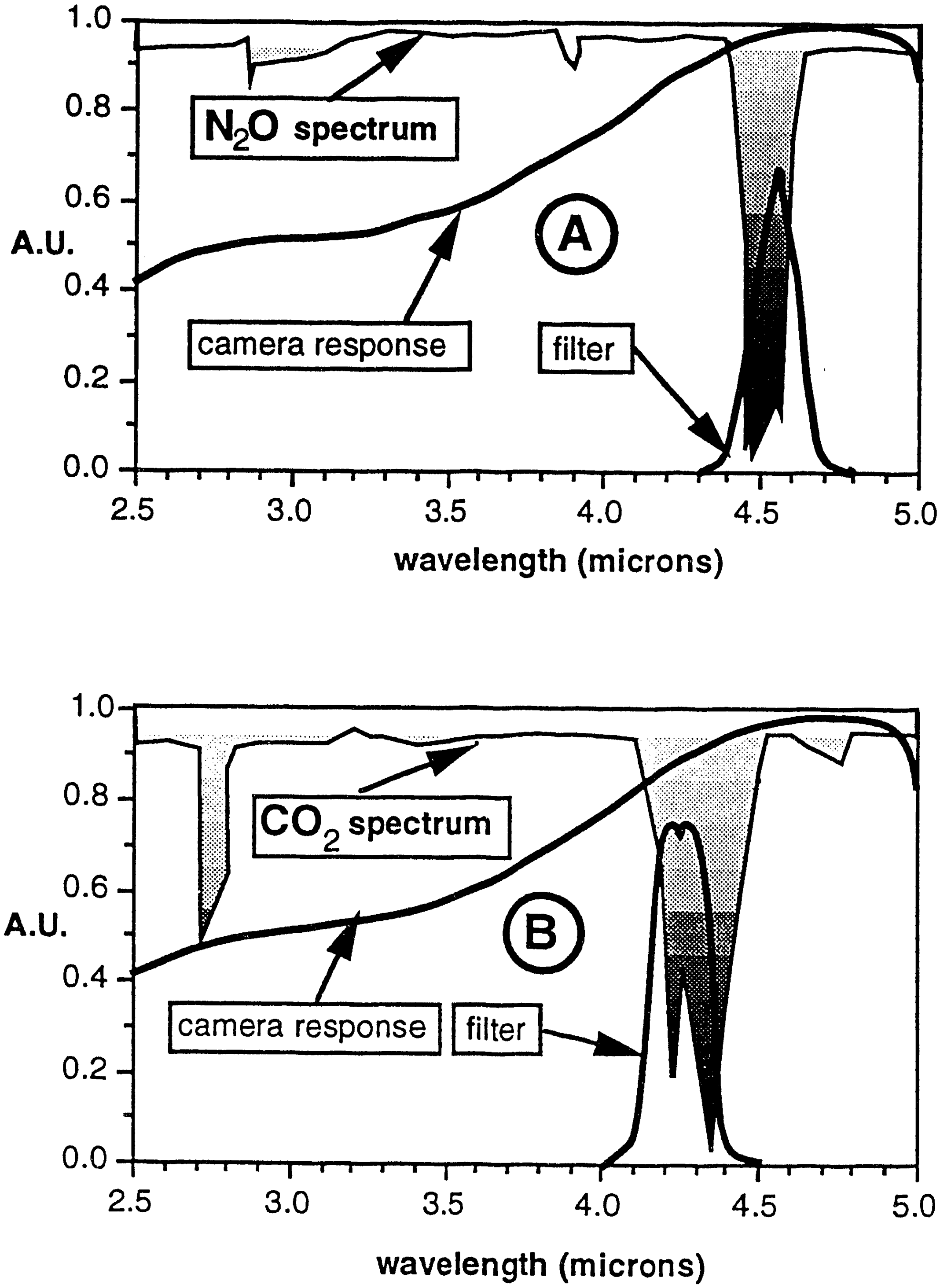
ACKNOWLEDGEMENT

This work was supported by the United States Department of Energy, Office of Basic Energy Sciences, under contract W-31-109-Eng-38.

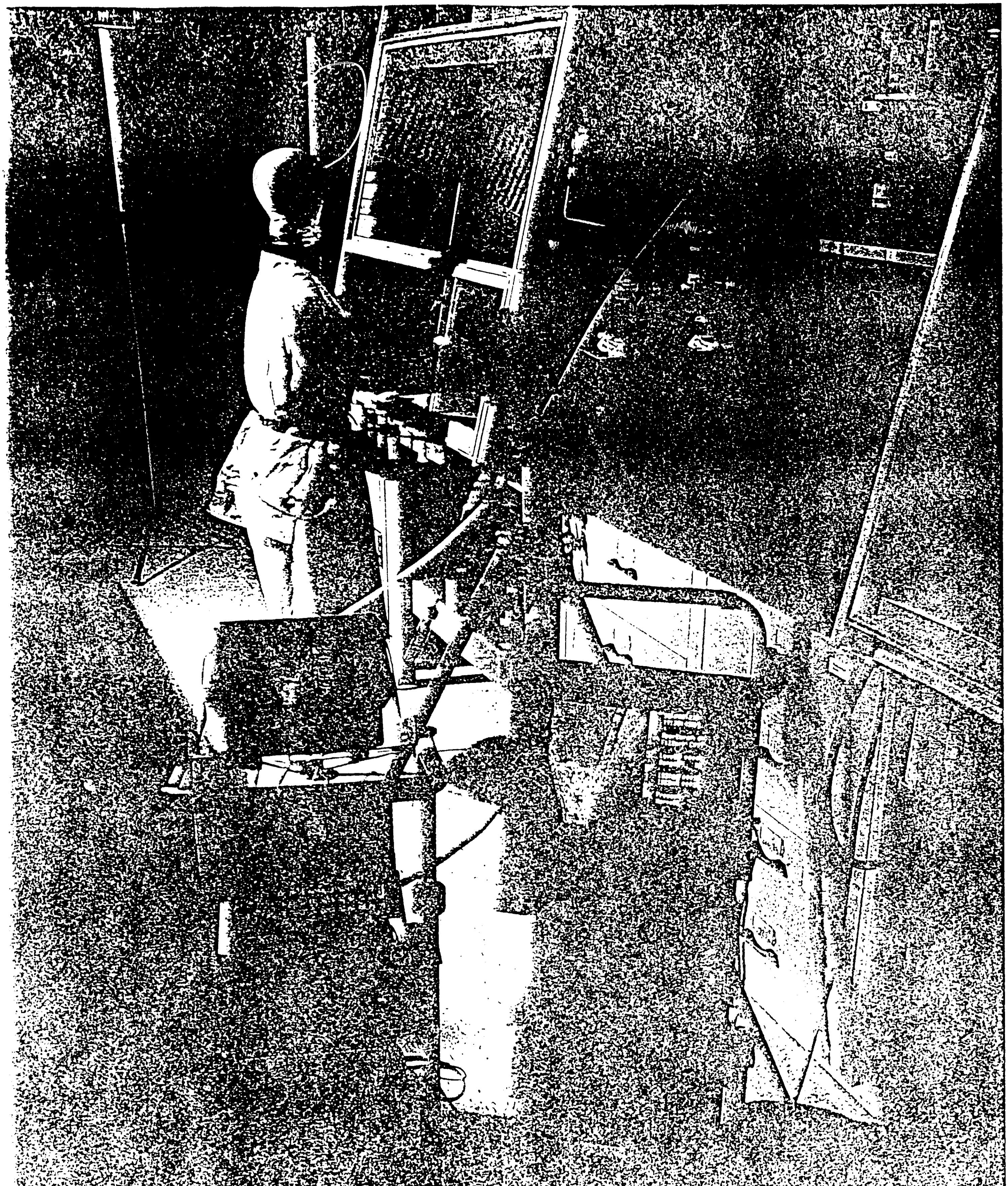
Figure Legends

Figure 1. Composite figures of the infrared camera response, narrow band-pass filter and intensity of light absorption by different gases vs. wavelength, in arbitrary units (A.U.). For the camera, the greatest response is at 1, for the gas and the companion filter, a value of zero indicates opacity, while 1 would indicate total transparency. A: nitrous oxide. B: carbon dioxide.

Figure 2. Photograph of the experimental setup. In the forefront are two portable electronics bays on which can be seen the monitors with the video images, then the camera, the gas delivery system on the bench to the right of the camera, the mannikin in front of the hood, and the black rectangular heat curtain.



Mulac et al   Figure 1



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