Continuous Monitoring of Environmental Parameters in Underground Coal Mines

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Abstract

The development of personal and fixed-site continuous monitoring devices offers the potential to improve monitoring of the work environment and control worker exposure in underground coal mines. Such devices could allow continuous measurement as opposed to periodic measurement of dust concentrations. Furthermore, worker exposure to excessive levels of dust could be minimized because mine personnel would be aware of the actual dust conditions in their work environment at all times, and appropriate action could be taken. Dust control parameters could be monitored continuously allowing problems to be identified and corrected immediately. This paper discusses the concepts of continuous personal and fixed-site monitoring devices and the need for the development of instrumentation to monitor parameters used to control dust continuously.

Introduction

The purpose of this presentation is to provide background information which led to the recommendation that the Mine Safety and Health Administration (MSHA) develop instrumentation capable of continuously monitoring dust levels and parameters used to control dust in underground coal mining operations.

On April 4, 1991, the U.S. Department of Labor announced the issuance of 4,710 citations by MSHA to over 500 companies for tampering with respirable coal mine dust samples at nearly 850 coal mines. These citations resulted in the proposal of civil penalties against mine operators totaling some $6.5 million. Concerned about potential tampering and its impact on the integrity of the program to control respirable coal mine dust, the Secretary of Labor directed MSHA to review the program thoroughly and make recommendations for its improvement.

In response to the Secretary's directive, MSHA established the Coal Mine Respirable Dust Task Group (hereafter referred to as the "Task Group") to review relevant information and to study and recommend improvements to the Agency's respirable dust control program. In conducting its review, the Task Group conferred with

MSHA officials involved in the program; representatives of other government agencies, including the Bureau of Mines (BOM) and the National Institute for Occupational Safety and Health (NIOSH); and representatives from the mining community, as well as other interested parties.

The Task Group concluded that new technology for continuous monitoring of dust levels in the mine environment and of the parameters used to control dust offered the potential to further improve miner protection from excessive levels of respirable coal mine dust and improve the integrity of the enforcement program[1]. Accordingly, the Task Group formulated recommendations that focused on the development and implementation of new and improved technology for continuously monitoring dust levels and parameters used to control dust.

The estimated time to implement these new technologies was several years. Therefore, the Task Group also recommended improvements in the existing enforcement program. These recommended improvements concerned monitoring, dust control, training, surveillance, and the role of the miner. Presently, as a result of these recommendations, MSHA has implemented a new dust cassette, is investigating no or low-weight gain samples, has proposed a single-sample noncompliance determination in the inspection program, has reviewed all dust control plans, has proposed certification and decertification regulations, has improved education and training plans, and has assisted NIOSH in the National Coal Study.

Recommendations for Continuous Monitoring of the Mine Environment

The Task Group found that technology is at the threshold where fixed-site dust monitors and dust control parameter monitors can be developed. Monitors strategically located in the workplace or mounted on the mining equipment would permit the environment of the mine and the parameters essential to the control of dust to be monitored continuously. Information provided by continuous monitoring devices would give real-time data that can be used by mine personnel to achieve control of hazardous dust levels. The information could also be transmitted to a central data-gathering site for processing. Although the development of monitors is feasible with existing state-of-the-art technology, the Task Group recognized that a commitment of resources would be required in the area of research to develop and evaluate this instrumentation and integrate it into the mining industry.

To achieve the goal of continuously monitoring dust levels and dust control parameters in the mine environment, the Task Group recommended the following actions:

- An accelerated research program to evaluate existing state-of-the-art technologies having the potential to be used in the development of a fixed-site underground coal mine dust monitor. Applicable technologies to be considered were light scattering, tapered element oscillating microbalance and beta-sensing gauges. The ultimate goal was to have an instrument that could be used to provide continuous information to the miner and mine operator on the status of dust resulting from the mining process, as well as information on the status of compliance with respect to the applicable respirable dust standard. The application of such a monitor was expected to be similar to that of the current methane monitor.

- An accelerated research program to develop instrumentation for continuously monitoring parameters such as ventilating air quantity, water consumption, entry velocities, etc. used to control dust.

- A research program to develop a device for measuring full-shift personal respirable dust exposures and for use as a hand-held detector for determining the efficacy of methods used to control dust. This would be a device similar to the MINIRAM, an instantaneous dust-measuring instrument that uses the principle of light scattering to measure the amount of dust in the environment. However, unlike the MINIRAM, the instrument developed should provide a direct measure of the mass of dust to which an individual is exposed. The desired device would be capable of providing both a short-term measurement and a determination of the average full-shift respirable dust exposure. In designing the instrument, emphasis should be placed on minimizing the weight and size of the unit and optimizing resistance to tampering.

Status of Recommendations

Bureau of Mines

In response to the Task Group's recommendations, the BOM adjusted their priorities and implemented an accelerated research program costing approximately $1 million for the development of instrumentation to monitor the mine environment and parameters

used to control dust continuously. Under their accelerated program, three major efforts were initiated:

1. A contract was awarded for research aimed at the development of new, or novel particulate mass-measuring technology.

2. A contract was awarded for the modification and ruggedization of commercially available technology.

3. An in-house effort was initiated to develop methodology for real-time measurement of parameters used to control dust. This included the measurement of water pressure and quantity, air velocity, machine tram speed, and power usage.

The contract[2] for the development of a novel sensor for measuring the mass concentration of dust in the environment was awarded in September, 1992. The objective of the novel sensor contract, titled "The Resonant Filter Membrane Mass Monitor (RFM3)", was to measure the mass of dust, in real time, collected on a vibrating filter. The sensor is designed around the principle that the frequency of the oscillating filter will shift in direct proportion to the mass of dust deposited on the filter. The initial developmental phase of the contract was completed in May, 1994. Hardware developed under the contract has been delivered to the BOM and is currently under evaluation. This hardware is shown on Figure 1.

The contract[3] for the modification and ruggedization of commercially available equipment was awarded to a company that manufactures systems for measuring minute quantities of dust collected during environmental sampling. The systems use a tapered element oscillating microbalance (TEOM) as the principle of measurement. The system, shown in Figure 2, uses a filter mounted on the end of a vibrating element. As dust is collected on the filter, the frequency of oscillation of the element changes in direct proportion to the mass of dust collected on the filter. Because of the sensitivity of the sensor, real-time mass concentrations can be determined in a matter of minutes. While the system is sensitive and has the capability of providing a real-time measurement, the commercially available units are relatively large and sensitive to shock and vibration, making them unsuitable for use in underground mine environments. Consequently, the primary objective of the contract is to reduce the unit's size, make it suitably rugged for use in mine environments, and develop technology that would eliminate measurement bias due to environmental moisture (water droplets).

This contract is currently in its second phase. The initial phase was to determine and demonstrate that the system could be

modified to withstand the rigors of the mine environment and the forces of shock when mounted on a piece of operating mine equipment. During this second phase of the contract, modified systems will be tested and evaluated in several underground mines. Upon successful demonstration of underground testing, 10 units will be manufactured for evaluation by the BOM. These 10 units are scheduled to be available during the first quarter of 1996.

The in-house effort by the BOM to develop instrumentation for continuous monitoring of parameters used to control dust has been completed. Existing technology and hardware were assembled into a package that provides continuous monitoring and recording of the pressure and quantity of water supplied to a mining machine, the velocity of air being supplied to the workplace, and the tram speed and power usage of the mining machine. The package has been successfully tested in a full-scale laboratory mockup of a longwall face, and has been scheduled for full-scale testing in an underground mine. The main objective of the in-mine testing is to demonstrate that by monitoring and optimizing parameters that are known to have an impact on dust generation, problems can be quickly identified and corrected so that dust levels can continuously be maintained within acceptable levels.

Mine Safety and Health Administration

In addition to the accelerated research activities of the BOM, the MSHA initiated a program to gather information that would be needed to develop a program for utilizing a fixed-site continuous monitor for ensuring environmental dust levels would be maintained within acceptable levels. MSHA's program consisted of assembling three personal respirable coal mine dust samplers into a package that permitted continuous sampling of the mine environment. The package, shown in Figure 3, was designed so that it could be located in the vicinity of the machine operator. The package was interfaced with a datalogging device and was designed so that power to operate the samplers was obtained from the mining machine. The package was programmed so that each of the three samplers would sample a different shift on the same day and would repeat itself for five days. This provided the average five-day respirable dust concentration for each of the three work shifts. In addition to the average five-day shift concentration, information was obtained on production and mining machine operating time.

Data gathering with the package commenced in October of 1993. To date, over 25 weeks of comparative data has been obtained. Attempts are currently under way to gather additional data to

determine how well measurements obtained with the fixed-site monitor compare with measurements obtained on the continuous miner operator.

Epilogue

As a result of the MSHA's respirable dust enforcement program by the Agency’s Assistant Secretary, an extensive research effort was initiated for the development of technology that could provide continuous monitoring of the mine environment. The development and utilization of this technology could provide both MSHA and the coal mining industry with the tools necessary to insure that respirable coal mine dust concentrations in the nation's underground coal mines are continuously maintained at statutory levels.

Disclaimer

Reference to specific products does not imply endorsement by the Mine Safety and Health Administration.

References

1. U.S. Department of Labor, Mine Safety and Health Administration: Review of the Program to Control Respirable Coal Mine Dust in the United States. Report of the Coal Mine Respirable Dust Task Group. U.S. Department of Labor, Washington, D.C. (June, 1992).

2. U.S. Bureau of Mines Contract 1432-H0329016: Development of Resonant Filter Membrane Respirable Coal Mine Dust Mass Monitor (1992).

3. U.S. Bureau of Mines Contract 1432-H024001: Adaption of the Tapered-Element-Oscillating Microbalance as a Continuous Dust Monitor for Coal Mines (1994).

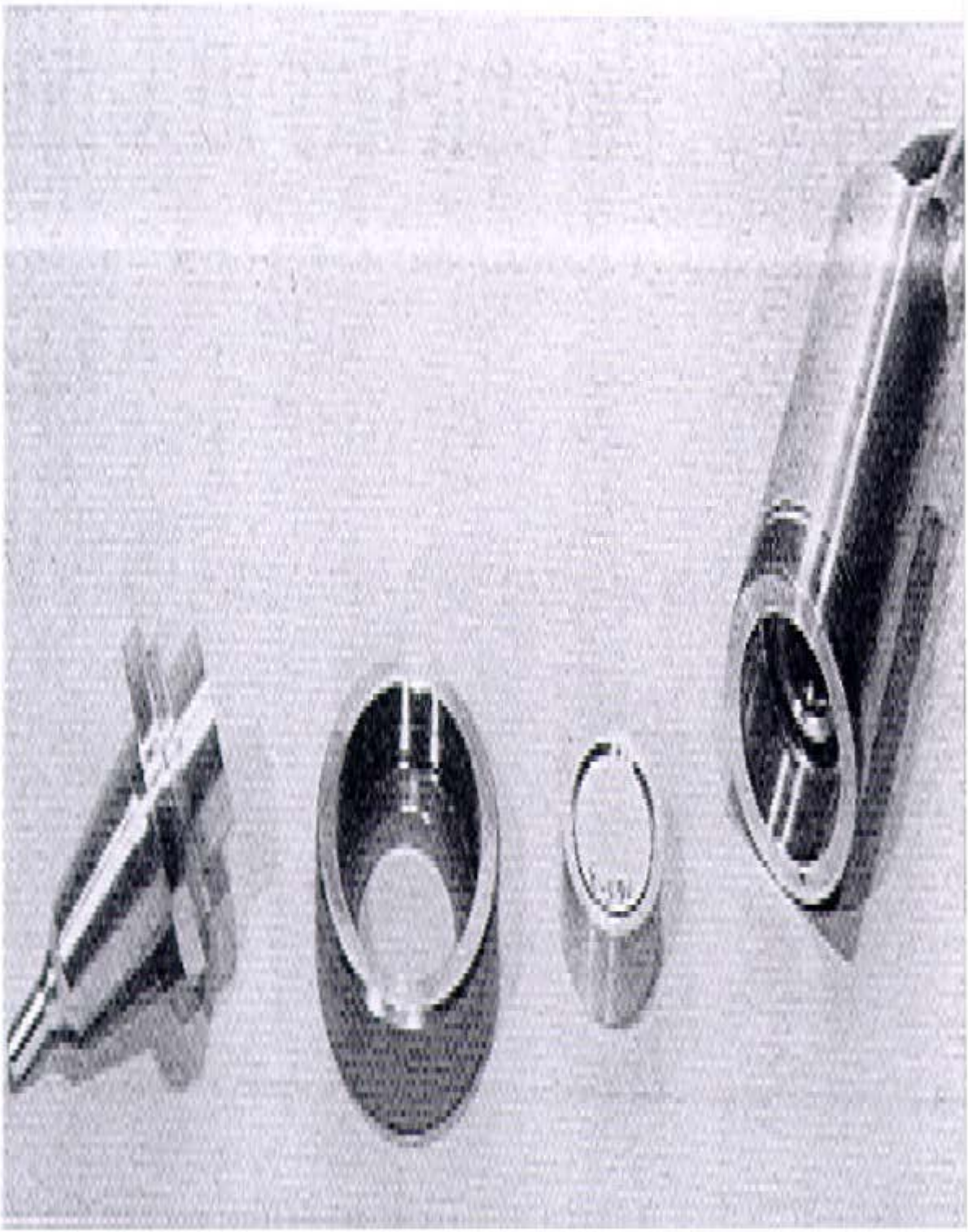

Figure 1. Components of the Resonant Filter Membrane Mass Monitor (RFM3).

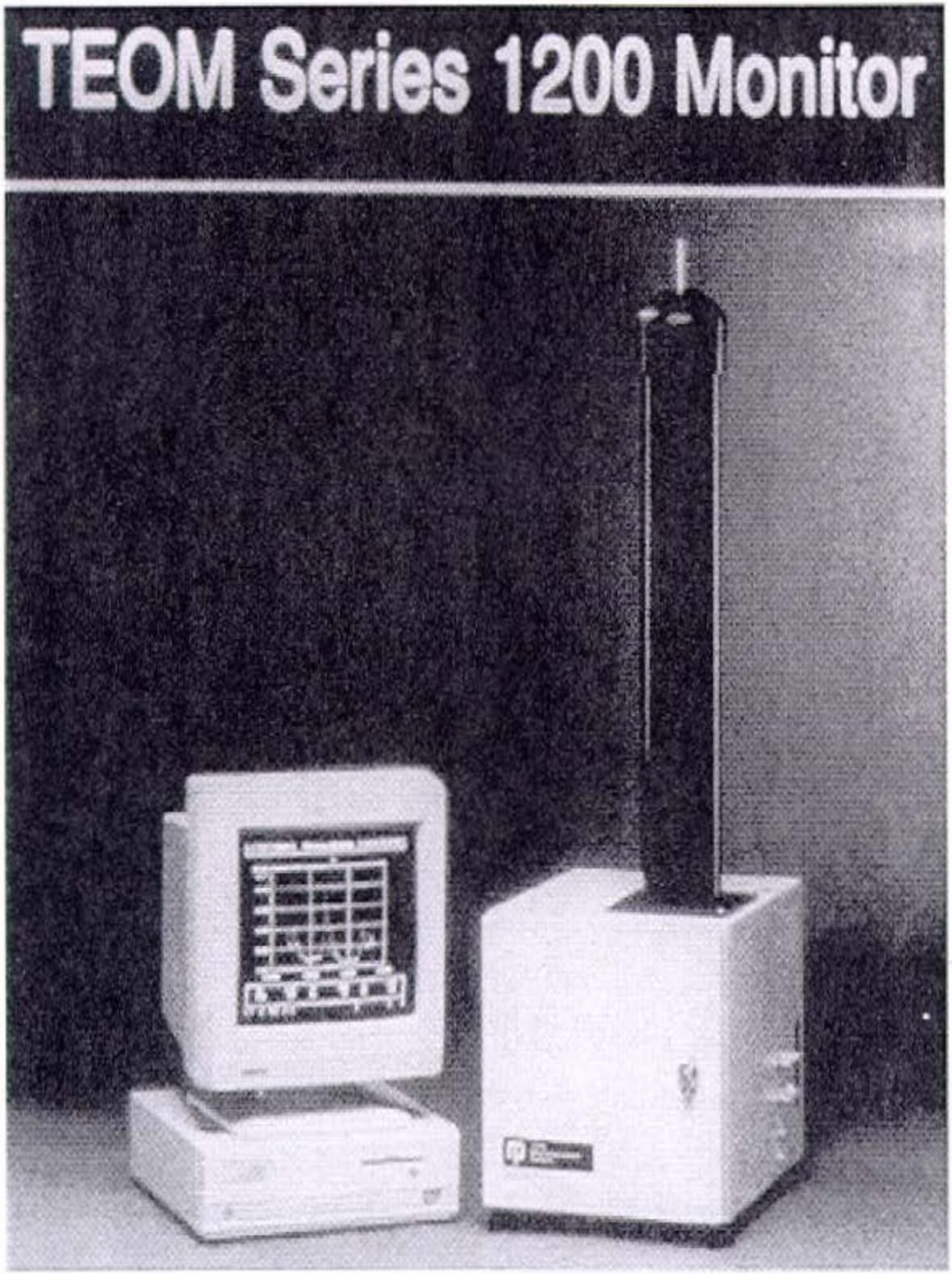

Figure 2. Commercially available tapered element oscillating microbalance.

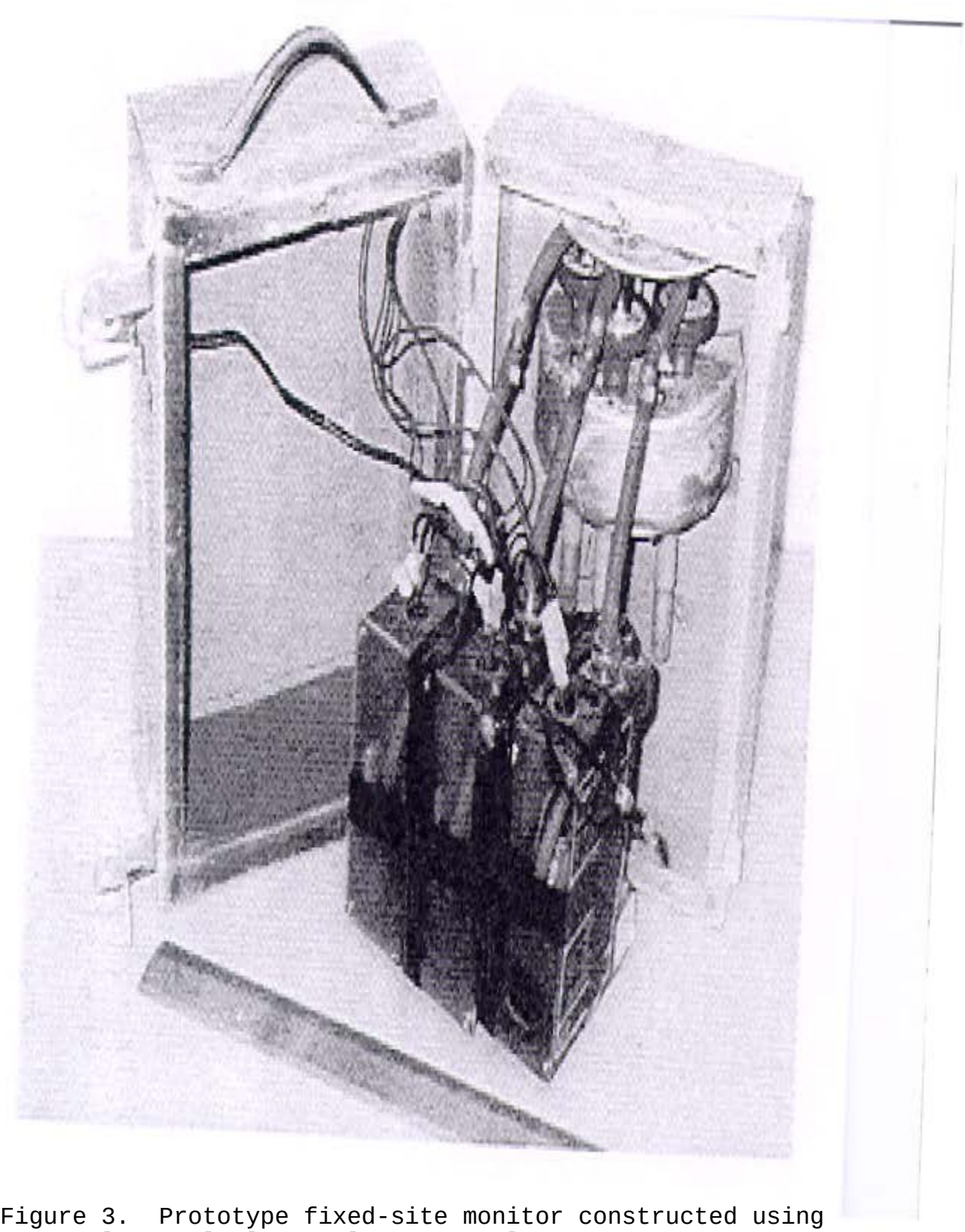

Figure 3. Prototype fixed-site monitor constructed using currently available sampling technology.