series of grab samples and the average obtained from an integrated continuous sample.

At first glance one might say that the difference here of 21 p.p.m. between the two methods is within the experimental error of the interferometer and assume the combustion result to be correct. However, although there is a probable error of 20 p.p.m. for one reading on the interferometer, for a series of readings the result obtained is much closer to the correct one, and probabilities are that the combustion apparatus gave slightly low results,[34] especially for the period of time that the concentration was above 500 p.p.m. The correct result may well be assumed to have been 5 to 15 per cent above the combustion results, or between 107 and 117 p.p.m.

The graph is an interesting illustration of another point, that is, of the futility of trying to evaluate a variable exposure by a single, or even a few, random grab samples. To be reliable the grab samples must be taken at frequent regularly spaced intervals. These particular samples represent an abnormal variation in concentration in that the spillage was frequent and variable, with constantly good general ventilation. Under such conditions, if the chief concern is maximum level of contamination, the industrial hygienist will choose properly spaced grab samples; if toxicity is more dependent upon cumulative exposures, he may prefer the integrated sample.

B. ADSORPTION FOR EVALUATION BY WEIGHT

Many variations of the adsorption method introduced by Greenburg[35, 36] have been proposed by different investigators. The principle is the same in all and the shortcomings are similar. The usual adsorbent is activated charcoal or silica gel confined in convenient weighing tubes. These materials are not selective but readily adsorb most vapors and gases, especially those of high molecular weight. The sample of vapor in air is drawn through the adsorbent at a constant rate, usually 1 liter or less per minute, and after a suitable sample is collected the tube with its contents is weighed. Since practice has shown that variations in weight of silica gel tubes, and even more so of charcoal tubes, often amount to more than 5 mg. within a 24-hour period as a result of static charges, moisture, and other factors, even though no air has been passed through them, it is obvious that dependable results require samples weighing at least 50 mg. If the sample is collected at the rate of 1 liter per minute, and it is desired to determine the concentration of benzene in the air of a room where the average concentration amounts to 50 p.p.m. (0.16 mg. per liter), it is evident that a sampling time of about 5 hours would be required for dependable results. In higher concentrations this method is more applicable, since less time is required to obtain a sample of suitable weight. Tubes equilibrated for several hours in air of the same humidity and temperature as the atmosphere to be analyzed may be used without filters for removing water vapor and carbon dioxide from the air sampled. However, it is the usual practice in the interest of accuracy to employ such filters wherever they do not alter the concentration of the contaminant, and Moskowitz and Burke[37] found it advantageous to have filters before and after the adsorbent. The ones ahead of the adsorbent removed water and carbon dioxide from the air, and the ones following the adsorbent collected water and carbon dioxide lost by the adsorbent as the air passed over it. The adsorption method obviously collects an integrated sample, while it is frequently desirable to follow the changes in concentration in order to obtain information on the height and duration of peak values. The method is applicable to gases and vapors of high molecular weight and moderate toxicity. It must always be borne in mind that many vapors cannot be filtered through drying agents and soda lime without partial or even complete loss within those agents. Since the method warrants an accuracy only to the nearest milligram, weighing usually can be accomplished at any laboratory or in the field. Vapor samples adsorbed on activated carbon or silica gel may also be transported to the laboratory, released by passing heated air through the adsorbent, and the vapor determined by suitable chemical methods of analysis. (Refer also to pages 210 and 211.)

[34] F. H. Goldman and C. G. Seegmiller, *J. Ind. Hyg. Toxicol.*, *25*, 181 (1943).
[35] L. Greenburg, *U. S. Pub. Health Repts.*, *41*, 1516 (1926).
[36] W. A. Cook and A. L. Coleman, *J. Ind. Hyg. Toxicol.*, *18*, 194 (1936).

C. CONDENSATION AT LOW TEMPERATURES

Most vapors may be collected successfully by drawing them through a suitable chamber immersed in a low-temperature bath, the temperature required being that at which the vapor pressure of the liquid or solid to be collected approaches zero. A metering device for the air mixture is necessary, and the rate must be slow enough to permit condensation and avoid loss of mist or dust of the condensed material. The design of the condensation chamber must be such as to avoid choking with either ice or solid contaminant condensed from the air sampled. The condensed material may be weighed, measured by volume, or determined by quantitative chemical analysis. Ice, solid carbon dioxide, and liquid air have each been employed as the refrigerating medium.

D. COLLECTION BY ABSORPTION OR ADSORPTION FOR LABORATORY ANALYSIS

The collecting device here may be any of several types of scrubbers or impingers, and the collecting medium may be granulated silica gel or a liquid of low volatility, either of which must be a tenacious adsorbent or absorbent for the contaminant or else it must fix the contaminant by chemical combination. The collectors may be used singly or in series depending upon their established efficiency. The collected samples are transported to the laboratory and evaluated by various means, which include colorimetric, volumetric, polarographic, or spectrographic analyses, the use of the ultraviolet or infrared spectrometer, and combustion. (Refer also to pages 208 and 214.)

E. SAMPLING IN EVACUATED BOTTLES

1. Vacuum Bottle Samples

Samples are conveniently collected in vacuum bottles for the determination of oxygen, carbon dioxide, and combustible gases in the analysis of mine gases by

[37] S. Moskowitz and W. J. Burke, *N. Y. State Ind. Bull.*, *17*, 168 (1938).