METHOD AND APPARATUS FOR PROVIDING DILUENT GAS TO EXHAUST EMISSION ANALYZER

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. Ser. No. 08/536,401 filed Sep. 29, 1995 now U.S. Pat. No. 5,756,360.

BACKGROUND OF THE INVENTION

This invention relates to a gas sampling device to measure the concentration of exhaust substances (i.e., emissions of, for example, CO, CO_2, hydrocarbons HC, NO_x, SO_x and the like) contained in the exhaust gas of an automotive vehicle.

A conventional method of measuring the mass of components in exhaust gases uses the CVS (Constant Volume Sampling) method. The CVS method continuously dilutes all of the exhaust gases from an engine with ambient air to a constant and known volume flow rate. The constant flow rate is controlled by drawing the diluted exhaust gases through a volumetric measuring device such as a critical flow venturi or a positive displacement pump. By continuously collecting a small fraction of the total diluted flow in a bag during a test cycle, the mass of a component can be determined by measuring the concentration of the component in the bag at the end of a test and multiplying by the total diluted volumetric flow measured during the test. The CVS method works well as long as the concentration of the component measured is large compared to the concentration of that component in the dilution air. As progress is being made in the reduction of the mass of pollutants emitted from an engine, the contribution made to the measurement by the diluent is no longer negligible. In fact, sometimes the concentration of a pollutant in the diluent air is larger than the concentration in the exhaust gas. An obvious solution to this situation is to use a purified diluent instead of ambient air. For the CVS technique, this is an expensive and impractical approach because of the large volumes of diluent required. Typically the minimum volume of diluent required is eight to ten times the maximum instantaneous exhaust gas flow rate. This large quantity of diluent is necessary in order to reduce the dew point of the gas mixture to below ambient temperature, thereby preventing condensation of the moisture present in the exhaust gas.

An alternate technique to measure mass emissions and avoid measuring the pollutants in the dilution air is to measure the exhaust concentrations before CVS dilution and separately determine the exhaust mass flow. Additional flow measurements must be made to utilize this method.

To determine the instantaneous mass flow of an exhaust component using the CVS method, the following technique can be used. The instantaneous exhaust gas flow rate can be calculated by measuring the diluent flow rate into the CVS with a flow measurement device such as a smooth approach orifice and mathematically subtracting this from the CVS flow rate. By using the instantaneous exhaust flow rate and the undiluted exhaust concentrations the instantaneous mass emissions of any component may be determined.

In order to measure the concentration of exhaust gas components directly, analysis must either be done at elevated temperatures in specially designed instrumentation or the water which condenses when the exhaust gas is cooled must be removed before analysis. Both of these approaches have disadvantages. Instruments designed to operate at elevated temperatures are expensive and usually require considerable care and maintenance. Analysis on a "wet basis" is desirable to eliminate the errors introduced by removing the water from the sample. When the water vapor in the gas is condensed and removed, some of the pollutants are removed with the water. The concentrations indicated when analyzing a sample on a "dry basis" are higher than "wet basis" analysis due to the decrease in volume caused by removal of the water. The "wet basis" analysis can only be approximated from the "dry basis" analysis. The residual errors are undesirable.

SUMMARY OF THE INVENTION

According to the present invention, a small quantity of undiluted exhaust gas is extracted and diluted with contaminant-free air or nitrogen producing a mixture having a dew point below ambient temperature and satisfying the flow requirements of the analysis system. Analysis is performed at ambient temperature without water extraction or loss of any exhaust emissions components. The undiluted concentrations are readily obtained by multiplying the diluted sample concentrations by the dilution ratio.

This invention is adapted to be used for analyzing exhaust emissions by using a small fraction of a continuously-extracted exhaust sample combined with a pollutant-free diluent through a system of critical flow orifices at a predetermined and precisely controlled flow ratio. The apparatus and method of the present invention includes the general steps of: (1) Determining the working dilution ratio; (2) introducing calibration gases to establish the operating-dilution ratio; (3) extracting an aliquot of high dew point exhaust gas; (4) diluting the exhaust gas sample with a dry, pollutant-free diluent; (5) maintaining the exhaust gas at a temperature above the dew point of water through dilution; and (6) delivering the diluted exhaust gas to the analysis system at a sufficient flow rate to satisfy the flow requirements of the gas analysis system. Once delivered to the analyzer, the diluted gas can then be analyzed and the undiluted pollutant concentrations obtained by multiplying by the dilution ratio. In practice, the dilution ratio is determined by analyzing the undiluted calibration gas and dividing that concentration by the concentration of the diluted calibration gas produced by the diluter as determined by the analyzer system.

According to the present invention, sample and diluent flow orifices have throat sizes that are properly sized to accurately establish the dilution ratio of diluent gas to exhaust gas. The inlet pressure to the diluent orifice is controlled to a pressure equal to the sample orifice inlet pressure by a pneumatic relay. The sample and diluent orifices exit into a common reduced pressure manifold. The manifold pressure is maintained at a reduced pressure sufficient to create critical flow through both orifices. By situating the orifices and related fluid lines within an oven, the temperature of the undiluted sample is maintained above the dew point of exhaust gas, thus eliminating condensation problems. This oven arrangement also maintains the orifices at equal temperatures, thus circumventing dilution ratio variations.

The sample and diluent orifices are preferably of the critical flow variety, however (or alternately) critical flow venturis, subsonic orifices, or subsonic venturis may be substituted for the critical flow orifices. The invention maintains constant dilution ratio with subsonic orifices and subsonic venturis by maintaining equal pressure at the inlets and equal, reduced pressure at the outlets of the sample and dilution orifices or venturis.

The diluted gas produced by any embodiment of the diluter of the present invention may then be analyzed to