Claims

1. An analyzer for one or more gases derived from a first gas of known composition and speed of sound, each derived gas having a concentration of a component changed, the analyzer comprising:

a first transducer, the first transducer driving continuous sound waves responsive to a fixed frequency signal source;

a conduit acoustically connected to the first transducer, the conduit selectively receiving and holding samples of the first gas and one or more derived gases;

a second transducer acoustically connected to the conduit opposite the first transducer, the second transducer receiving sound waves from the first transducer through the conduit and generating second transducer signals responsive to the received sound waves;

a processing unit receiving fixed frequency signal source signals and the second transducer signals, the processing unit determining a relative phase shift between the frequency source signals and second transducer signals for a gas sample in the conduit, the relative phase shift corresponding to a difference of speed of sound in one gas sample relative to another gas sample, the processing unit including circuitry lowering the frequency of the received fixed frequency source signals and second transducer signals to expand the range of measurement of the relative phase shift; and

a calculating unit determining from the known speed of sound of the first gas and the relative phase shift the speed of sound of the one or more gases derived from the first gas, and calculating the composition of a sample of one or more derived gases from the first gas as a reference.

2. The analyzer of claim 1 wherein the circuitry lowering the fixed frequency of the frequency source signals and second transducer signals each comprises a frequency divider circuit.

3. The analyzer of claim 2 wherein the frequency divider circuit comprises a digital counter circuit.

4. The analyzer of claim 3 wherein the frequency divider circuit divides by a divisor having a value of a power of 2.

5. The analyzer of claim 4 wherein the frequency divider circuit divides by 8.

6. The analyzer of claim 1 wherein the first gas comprises air.

7. The analyzer of claim 6 wherein a first derived gas comprises air with an increased concentration of oxygen.

8. The analyzer of claim 7 wherein a second derived gas comprises air with an increased concentration of ozone.

9. The analyzer of claim 3 wherein the digital counters of the frequency dividers have baselines adjusted so that the range of measurement of the phase shift is expanded and the range of calculation of gas composition is increased.

10. The analyzer of claim 1 wherein the calculating unit calculates the concentration of the component changed in the sample of the one or more derived gases.

11. The analyzer of claim 10 wherein the concentration of the component changed in the sample of the one or more derived gases is calculated principally from the proportion of the changed component in the sample of the one or more derived gases.

12. The analyzer of claim 11 wherein the proportion of the changed component in the sample of the one or more derives gases is calculated from a ratio having the determined speed of sound of the sample of the one or more derived gases in the numerator and a speed of sound of 100 percent of the changed component in the denominator.

13. The analyzer of claim 11 wherein the calculation of the concentration of the component changed in the sample of the one or more derived gases includes modifying empirical correction factors.

14. The analyzer of claim 1 wherein the conduit is maintained at a selected temperature.

15. The analyzer of claim 14 wherein the conduit comprises an ozone-resistant tubing enclosed in a metal block to provide a thermal mass to the conduit.

16. The analyzer of claim 15 wherein the ozone-resistant tubing comprises polytetrafluoroethylene (PTFE) and the metal block comprises aluminum.

17. The analyzer of claim 2 wherein the conduit has a path length L between the first and second transducers wherein L has a removed constraint from the frequency divider circuit of:

$L < \lambda_{min} \cdot \lambda_{max} / (\lambda_{min} - \lambda_{max})$ or $L < \frac{1}{2}\lambda_{min} \cdot \lambda_{max} / (\lambda_{min} - \lambda_{max})$

depending upon whether the processing unit limits the relative phase shift to 360 degrees or to 180 degrees respectively, where λ_{min} = minimum wavelength and λ_{max} = maximum wavelength of the first gas and one or more gases.

18. The analyzer of claim 17 wherein the conduit has a path length L:

$L < n\lambda_{min} \cdot \lambda_{max} / (\lambda_{min} - \lambda_{max})$ or $L < \frac{1}{2} n\lambda_{min} \cdot \lambda_{max} / (\lambda_{min} - \lambda_{max})$

depending upon whether the processing unit limits the relative phase shift to 360 degrees or to 180 degrees respectively, and n comprises a divisor for the frequency divider circuit.

19. The analyzer of claim 18 wherein the conduit path length L is more than 10 wavelengths of the first gas.

20. The analyzer of claim 19 wherein the conduit path length L is less than 30 wavelengths of the first gas.

21. A method of operating an analyzer for one or more gases derived from a first gas of known composition and speed of sound, each derived gas having a concentration of a component changed, the method comprising:

driving continuous sound waves with a first transducer in response to fixed frequency electrical signals through a conduit holding a sample of the first gas or one or more derived gases at a time;

receiving the sound waves driven through the conduit by a second transducer and generating electrical signals in response to the received sound waves, a phase shift between the received sound wave signals and the driven sound wave signals corresponding to a speed of sound in the gas sample;

processing the fixed frequency electrical signals and the electrical signals generated signals in response to the received sound waves at a lowered frequency to expand the range of measurement of the phase shift to determine a relative phase shift between the frequency source signals and second transducer signals for a gas sample in the conduit, the relative phase shift corresponding to a difference of speed of sound in one gas sample relative to another gas sample;

determining a speed of sound of one or more gases derived from the first gas from the known speed of sound of the first gas and from the relative phase shift of gas samples of the first gas and one or more gases derived from the first gas in the conduit, and

calculating a composition of a gas sample of one or more gases derived from the first gas as a reference.

22. The method of claim 21 wherein the processing step includes lowering the frequency of the fixed frequency electrical signals and the electrical signals generated signals in response to the received sound waves.

23. The method of claim 22 wherein the frequency lowering step comprises dividing the frequency by divisor having a value of a power of 2.

24. The method of claim 23 wherein the frequency lowering step comprises dividing the frequency by 8.

25. The method of claim 21 wherein the first gas comprises air, a first derived gas comprises air with an increased concentration of oxygen, and a second derived gas comprises air with an increased concentration of ozone.

26. The method of claim 21 wherein the calculating step comprises calculating the concentration of the component changed in the sample of the one or more derived gases.

27. The method of claim 26 wherein the component changed calculating step comprises calculating the concentration of the component changed in the sample of the one or more derived gases principally from the proportion of the changed component in the sample of the one or more derived gases.

28. The method of claim 27 wherein the component changed calculating step comprises calculating the proportion of the changed component in the sample of the one or more derived gases from a ratio having the determined speed of sound of the sample of the one or more derived gases in the numerator and a speed of sound of 100 percent of the changed component in the denominator.

29. The method of claim 27 wherein the component changed calculating step includes modifying the proportion of the changed component in the sample of the one or more derived gases with empirical correction factors.

30. The method of claim 21 further comprising maintaining the conduit at a selected temperature.

31. The method of claim 21 further comprising providing for a conduit having a path length of greater than 10 wavelengths of sound in air.

32. A method of determining the composition of one or more gases derived from a first gas of known composition and speed of sound, the method comprising:

driving continuous sonic waves through the conduit at a fixed frequency, a phase difference between sonic waves entering a conduit and leaving the conduit corresponding to a speed of sound of a gas in the conduit;

processing electronic signals corresponding to the continuous sonic waves entering the conduit and leaving the conduit at a lowered frequency to expand the range of measurement of the phase shift;

changing the gas in the conduit among the first gas and the one or more derived gases;

determining the speed of sound of the one or more gases derived from the first gas in the expanded range from a relative phase shift of gases of the first gas of known composition and the one or more derived gases, the relative phase shift corresponding to a difference of speed of sound in one gas sample relative to another gas sample; and

calculating a composition of the one or more derived gases from the first gas as a reference.

33. The method of claim 32 wherein each derived gas has a concentration of a component changed originally from the first gas.

34. The method of claim 32 wherein the processing step includes lowering the frequency of the continuous sonic waves entering the conduit and leaving the conduit at a lowered frequency to expand the range of measurement of the phase shift.

35. The method of claim 34 wherein the frequency lowering step comprises dividing the frequency by a divisor having a value of a power of 2.

36. The method of claim 35 wherein the frequency lowering step comprises dividing the frequency by a divisor equal to 8.

37. The method of claim 32 wherein the first gas comprises air, a first derived gas comprises air with an increased concentration of oxygen, and a second derived gas comprises air with an increased concentration of ozone.

38. The method of claim 32 wherein the calculating step comprises calculating the concentration of the component changed in the sample of the one or more derived gases.

39. The method of claim 38 wherein the component changed calculating step comprises calculating the concentration of the component changed in the sample of the one or more derived gases principally from the proportion of the changed component in the sample of the one or more derived gases.

40. The method of claim 39 wherein the component changed calculating step comprises calculating the proportion of the changed component in the sample of the one or more derived gases from a ratio having the determined speed of sound of the sample of the one or

more derived gases in the numerator and a speed of sound of 100 percent of the changed component in the denominator.

41. The method of claim 39 wherein the component changed calculating step includes modifying the proportion of the changed component in the sample of the one or more derived gases with empirical correction factors.

42. The method of claim 32 further comprising maintaining the conduit at a selected temperature.

43. The method of claim 32 further comprising providing for a conduit having a path length of greater than 10 wavelengths of sound in air.