Claims

1. A method comprising:

contacting a known consumable with a thermal component of an instrument to be tested such that the consumable and the thermal component form a thermal interface;

driving the thermal component using a periodic sine wave input based on a predetermined interrogation frequency;

measuring a plurality of temperature outputs from a thermal sensor responsive to driving the thermal component using the periodic sine wave input, the thermal sensor being positioned and configured to detect a temperature of the thermal component;

multiplying the plurality of temperature outputs by a reference signal in phase with the periodic sine wave input and calculating a resultant direct current (DC) signal component to determine an in-phase component, X;

multiplying the plurality of temperature outputs by a 90° phase-shifted reference signal and calculating the resultant DC signal component to determine a quadrature, out-of-phase component, Y;

calculating a phase offset responsive to the periodic sine wave input based on $\tan^{-1}(Y/X)$ or a tan 2(X,Y);

determining a thermal resistance value for the thermal interface using a calibrated resistance-phase offset equation and the calculated phase offset; and

comparing the determined thermal resistance value to a predetermined thermal resistance threshold value.

2. The method of claim 1, the determined thermal resistance value being above the predetermined thermal resistance threshold value, the method further comprising determining that the thermal component has a defect at the thermal interface based on the determined thermal resistance value being above the predetermined resistance threshold value.

3. The method of claim 1, the determined thermal resistance value being below the predetermined thermal resistance threshold value, the method further comprising determining that the thermal component is acceptable based on the determined thermal resistance value being below the predetermined thermal resistance threshold value.

4. The method of claim 1, wherein the thermal component comprises a thermoelectric cooler.

5. The method of claim 1, wherein the consumable comprises a flow cell.

6. The method of claim 1, wherein the predetermined interrogation frequency is determined based on an estimated RC corner value for the known consumable and the thermal component of the instrument.

7. A method comprising:

contacting a consumable to be tested with a known thermal component of an instrument, such that the consumable and the thermal component form a thermal interface;

driving the thermal component using a periodic sine wave input based on a predetermined interrogation frequency;

measuring a plurality of temperature outputs from a thermal sensor responsive to driving the thermal component using the periodic sine wave input, the thermal sensor being positioned and configured to detect a temperature of the thermal component;

multiplying the plurality of temperature outputs by a reference signal in phase with the periodic sine wave input and calculating a resultant direct current (DC) signal component to determine an in-phase component, X;

multiplying the plurality of temperature outputs by a 90° phase-shifted reference signal and calculating the resultant DC signal

component to determine a quadrature, out-of-phase component, Y;

calculating a phase offset responsive to the periodic sine wave input based on $\tan^{-1}(Y/X)$ or a tan 2(X,Y);

determining a thermal resistance value for the thermal interface using a calibrated resistance-phase offset equation and the calculated phase offset; and

comparing the determined thermal resistance value to a predetermined thermal resistance threshold value.

8. The method of claim 7, the determined thermal resistance value being above the predetermined thermal resistance threshold value, the method further comprising determining that the consumable has a defect at the thermal interface based on the determined thermal resistance value being above the predetermined resistance threshold value.

9. The method of claim 7, the determined thermal resistance value being below the predetermined thermal resistance threshold value, the method further comprising determining that the consumable is acceptable based on the determined thermal resistance value being below the predetermined thermal resistance threshold value.

10. The method of claim 7, wherein the thermal component comprises a thermoelectric cooler.

11. The method of claim 7, wherein the consumable comprises a flow cell.

12. The method of claim 7, wherein the predetermined interrogation frequency is determined based on an estimated RC corner value for the consumable and the known thermal component of the instrument.

13. A method comprising:

contacting a consumable with a thermal component of an instrument such that the consumable and the thermal component form a thermal interface;

driving the thermal component using a periodic sine wave input based on a predetermined interrogation frequency;

measuring a plurality of temperature outputs from a thermal sensor responsive to driving the thermal component using the periodic sine wave input, the thermal sensor being positioned and configured to detect a temperature of the thermal component;

multiplying the plurality of temperature outputs by a reference signal in phase with the periodic sine wave input and calculating a resultant direct current (DC) signal component to determine an in-phase component, X;

multiplying the plurality of temperature outputs by a 90° phase-shifted reference signal and calculating the resultant DC signal component to determine a quadrature, out-of-phase component, Y;

calculating a phase offset responsive to the periodic sine wave input based on $\tan^{-1}(Y/X)$ or a tan 2(X,Y);

determining a thermal resistance value for the thermal interface using a calibrated resistance-phase offset equation and the calculated phase offset;

comparing the determined thermal resistance value to a first predetermined thermal resistance threshold value;

comparing the determined thermal resistance value to a second predetermined thermal resistance threshold value; and

determining a characteristic of the thermal interface based on the comparison of the determined thermal resistance value to the first and second predetermined thermal resistance threshold values.

14. The method of claim 13, the determined thermal resistance value being below the first predetermined thermal resistance threshold value, the method further

comprising determining that the thermal interface is acceptable based on the determined thermal resistance value being below the first predetermined thermal resistance threshold value.

15. The method of claim 13, the determined thermal resistance value being above the second predetermined thermal resistance threshold value, the method further comprising determining that the consumable is not inserted in the instrument based on the determined thermal resistance value being above the second predetermined resistance threshold value.

16. The method of claim 13, the determined thermal resistance value being below the second predetermined thermal resistance threshold value and above the first predetermined thermal resistance threshold value, the method further comprising determining that a defect or debris is at the thermal interface based on the determined thermal resistance value being below the second predetermined thermal resistance threshold value and above the first predetermined thermal resistance threshold value.

17. The method of claim 13, wherein the thermal component comprises a thermoelectric cooler.

18. The method of claim 13, wherein the consumable comprises a flow cell used for sequencing by synthesis.

19. The method of claim 13, wherein the predetermined interrogation frequency is determined based on an estimated RC corner value for the consumable and the thermal component of the instrument.

20. A computer-readable medium having stored thereon a computer program comprising instructions to cause an instrument to execute the method of claim 13.