Claims

1. Apparatus for use in a wellbore, for use in sensing temperature in a wellbore, comprising:

tubing comprising at least 6 temperature sensor modules provided at locations along the inside of the tubing, said temperature sensor modules comprising temperature sensors provided at least in part by a resistive element whose electrical resistance is dependent on temperature;

an electrical network configured to electrically connect to the resistive elements to in use allow measuring of the respective electrical properties of the resistive elements to infer a thermal characteristic of the resistive element; and

at least one downhole control module electrically connected to multiple of said temperature sensor modules, via the electrical network, and configured to receive and process an electrical signal associated with the temperature sensor modules to enable inference of the temperature of the resistive elements and the environment to which the tubing is exposed at the location of that resistive element, and

wherein the tubing outer diameter is in the range of 3 mm to 14 mm at the location in the tubing of at least one of the temperature sensor modules.

2. Apparatus as claimed in claim 1, wherein the tubing is metallic.
3. Apparatus as claimed in any preceding claim, wherein the tubing outer diameter is in the range of 6 mm to 10 mm.
4. Apparatus as claimed in any preceding claim, wherein the outer diameter of the tubing is the same at locations in the tubing of at least one or all of the temperature sensor modules and at locations in the tubing away from the at least one or all of the temperature sensor modules.
5. Apparatus as claimed in any preceding claim, wherein the resistive element is a resistance temperature device (RTD), particularly a platinum or nickel based RTD.
6. Apparatus as claimed in claim 5, wherein the RTD is constructed of a wire coil, a wound wire, or a thin-film, particularly a thin-film deposited on a ceramic substrate.
7. Apparatus as claimed in claims 1 to 4, wherein the resistive element is a thermistor.
8. Apparatus as claimed in any preceding claim, wherein the tubing is filled with and encapsulates a non-conducting liquid, wherein the tubing comprises a pressure balancing means, configured to act to equalise internal pressure in the tubing with the ambient environment.

9. Apparatus as claimed in claim 8, wherein the pressure balancing means includes a bellows or flexible bladder.
10. Apparatus as claimed in any preceding claim, wherein the temperature sensor modules in the tubing are encased in a potting compound.
11. Apparatus as claimed in any preceding claim, wherein the tubing comprises plural wires; and wherein the wires and plural temperature sensors are configured such that the electrical network is arranged as a matrix by which the wires comprise a first group of wires and a second, different group of wires and each wire of the first group is electrically connected to each wire of the second group once, by different temperature sensor modules, such that each module can be individually electrically connected by a pair of wires comprising a first wire from the first group and a second wire from the second group.
12. Apparatus as claimed in any preceding claim, further comprising calibration means configured to compensate for the resistance of wires in the line that connect the resistive elements of the temperature sensors to the downhole control module, and also for the temperature dependence of the resistivity of those wires.
13. Apparatus as claimed in claim 12, wherein the calibration means is provided as part of the downhole control module.
14. Apparatus as claimed in any preceding claim, wherein the at least one downhole control module further comprises a common reference signal generator used as a reference for the measurement of the voltage and/or current of at least two or each of temperature sensor modules.
15. Apparatus as claimed in claim 14, wherein the common reference signal generator is a reference voltage source.
16. Apparatus as claimed in any preceding claim, wherein multiple control modules are provided downhole, wherein individual downhole control modules control sets of temperature sensor modules, and the control modules are linked to one or more master downhole control modules.
17. Apparatus as claimed in any preceding claim, wherein the tubing containing the temperature sensor modules is arranged as a ring or helix to extend around a tubular element of a well apparatus.
18. Apparatus as claimed in any preceding claim, further comprising a power source configured to provide operational power to the apparatus for sensing temperature in the wellbore in use, wherein the power source is arranged to be provided as an in-well power source in use, wherein the power source may be replaceable in the well.
19. Apparatus as claimed in claim 18, wherein the power source is a battery or power generator that may be replaced using wireline, or coiled tubing.

20. Apparatus as claimed in claim 18, wherein the power source comprises one or more primary cells, secondary cells and/or downhole power generators.
21. Apparatus as claimed in any of claims 1 to 17, wherein the apparatus is configured to be powered in use from a position higher in the well via inductive or capacitive coupling.
22. Apparatus as claimed in any preceding claim, further comprising a wireless data communication module coupled, wirelessly, by a separate wireless connection, or electrically by a wired connection, to the apparatus for use in sensing temperature in a wellbore and arranged to, in use:

    wirelessly transmit along the well signals indicative of a temperature sensed in the wellbore by the apparatus, using relays or repeaters.

23. Apparatus as claimed in claim 22, wherein the data communication module is configured to wirelessly receive control signals for controlling the operation of the apparatus, for control of data acquisition, data transmission, and/or to control heating or cooling of the sensors.
24. Apparatus as claimed in claim 22 or 23, wherein the wireless data communication module is configured to transmit said signals acoustically and/or electromagnetically.
25. Apparatus as claimed in any preceding claim, wherein the temperature sensor module comprises an electronic circuit configured to vary at least one of a current, a voltage, and a frequency with a temperature of the sensor.
26. Apparatus as claimed in any preceding claim, wherein the apparatus is configured such that, in use, at least one temperature sensor module is selected by the downhole control module digitally addressing the temperature sensor module, and wherein the selected temperature sensor module enables a voltage, current or frequency output representative of the temperature of a resistive element to be connected to the control module.
27. Apparatus as claimed in any preceding claim, wherein the temperature sensor module comprises a flexible printed circuit, particularly a flexible printed circuit less than 1mm thick, and/or particularly a flexible printed circuit comprising a polyimide or a polyaryletherketone substrate.
28. Apparatus as claimed in any preceding claim, wherein at least one, or each temperature sensor module comprises a single integrated electronic component incorporating the resistive element.
29. Apparatus as claimed in claim 28, wherein the maximum physical extent of the single electronic component in any axis is less than 7mm.

30. Apparatus as claimed in any preceding claim, wherein the downhole control module is configured to measure an analogue current, voltage and/or frequency associated with the temperature sensor modules to enable inference of the temperature of the resistive elements and the environment to which the tubing is exposed at the location of that resistive element.

31. A well comprising a well apparatus having apparatus for use in sensing temperature in a wellbore as claimed in any of claims 1 to 30 arranged to sense a temperature in a wellbore of the well.

32. A well as claimed in claim 31, wherein the well apparatus comprises an annular sealing device provided at least 100m below a surface of the well, and between a wellbore or a casing of the wellbore and a tubular.

33. A well as claimed in claim 32, wherein the apparatus for use in sensing temperature in a wellbore is provided entirely below the annular sealing device.

34. A well as claimed in claim 32, wherein the tubing of the apparatus for use in sensing temperature in a wellbore does not extend across the annular sealing device.

35. A well as claimed in any of claims 31 to 34, wherein the well apparatus comprises a tubular element and wherein the tubing of the apparatus for use in sensing temperature in a wellbore extends along and/or around the tubular element.

36. A well as claimed in claim 35, wherein the tubular element is a drill string and wherein the drill string comprises a drill bit or mill.

37. A well as claimed in claim 36, wherein the tubing is clamped to the tubular element in the well.

38. A well as claimed in any of claims 31 to 34, wherein the apparatus is deployed in the well on wireline, or coiled tubing, and set and/or suspended in the well.

39. A well as claimed in any of claims 31 to 37, wherein the tubing is clamped to and extends across a perforating gun or guns.

40. A well as claimed in claim 39, wherein the apparatus is configured to monitor the firing of the perforating gun.

41. A well as claimed in claim 39 or 40, wherein the apparatus, or a plurality of the apparatus, extend across multiple guns, and multiple perforating guns are independently activatable.

42. A well as claimed in any of claims 31 to 34, wherein the apparatus is configured to monitor the temperature at a barrier in the well.

43. A well as claimed in any of claims 31 to 41, wherein the apparatus is configured to monitor the well during a well test or drill stem test.

44. A well as claimed in any of claims 31 to 43, wherein the well is a production and/or injection well.

45. A well as claimed in claim 31 to 44, wherein the apparatus is configured to monitor an exothermic reaction associated with a fluid treatment of the well.
46. A well as claimed in any of claims 31 to 45, where the well is in a suspended or abandoned phase, and the apparatus is configured to monitor the well.

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