CLAIMS

1. A method for detecting a structural anomaly in a pipeline supply network, the pipeline supply network configured to supply fluid to multiple receiving locations, and wherein the structural anomaly comprises a leak in the pipeline supply network, the method comprising:

receiving acoustic signal data from a selected location in the pipeline supply network;

generating a first time window of acoustic signal data based on the acoustic signal data;

benchmarking the first time window of acoustic signal data with respect to historical background acoustic signal data characterising the pipeline supply network to generate a corresponding background benchmarked first time window of acoustic signal data, wherein benchmarking the first time window of acoustic signal data with respect to historical background acoustic signal data characterising the pipeline supply network includes:

determining an estimated spectral content difference between the first time window of acoustic signal data and the historical background acoustic signal data, wherein determining an estimated spectral content difference between the first time window and the background acoustic signal data includes:

determining the spectral content of the historical background acoustic signal data;

determining the spectral content of the first time window of acoustic signal data; and

determining in frequency space the difference between the spectral content of the background acoustic signal data and the spectral content of the first time window of acoustic signal data; and

removing the spectral content difference from the first time window of acoustic signal data to generate the corresponding background benchmarked first time window of acoustic signal data; and

determining an anomaly measure for the background benchmarked first time window of acoustic signal data, wherein the anomaly measure indicates a presence of the structural anomaly.

2. The method of claim 1, wherein removing the spectral content difference from the first time window of acoustic signal data includes:

applying in frequency space the spectral content difference to the spectral content of the first time window of acoustic signal data to generate a spectrally modified first time window; and

transforming the spectrally modified first time window to the time domain to generate the corresponding background benchmarked first time window of acoustic signal data.

3. The method of claim 1 or 2, further comprising on determining the presence of the structural anomaly in the background benchmarked first time window of acoustic signal data then:

generating a subsequent second time window of acoustic signal data;

benchmarking the subsequent second time window of acoustic signal data with respect to the first time window of acoustic signal data to generate a corresponding comparison benchmarked second time window of acoustic signal data;

determining the anomaly measure for the comparison benchmarked second time window of acoustic signal data; and

characterising the structural anomaly by comparing the anomaly measure determined for the background benchmarked first time window of acoustic signal data with the anomaly measure determined for the comparison benchmarked second time window of acoustic signal data.

4. The method of claim 3, wherein characterising the structural anomaly includes determining whether the structural anomaly is increasing, reducing or remains unchanged for a time period between the first and second time windows.

5. The method of any one of claims 3 or 4, wherein benchmarking the subsequent second time window of acoustic signal data with respect to the first time window of acoustic signal data includes:

determining the spectral content difference between the second time window of acoustic signal data and the first time window of acoustic signal data; and

removing the spectral content difference from the second time window of acoustic signal data to generate the corresponding comparison benchmarked second time window of acoustic signal data.

6. The method of claim 5, wherein determining the spectral content difference between the second time window and the first time window includes:

determining the spectral content of the first time window of acoustic signal data;

determining the spectral content of the second time window of acoustic signal data; and

determining in frequency space the difference between the spectral content of the first time window of acoustic signal data and the spectral content of the second time window of acoustic signal data.

7. The method of claim 6, wherein removing the spectral content difference from the second time window of acoustic signal data includes:

applying in frequency space the spectral content difference to the spectral content of the second time window of acoustic signal data to generate a spectrally modified first time window; and

transforming the spectrally modified second time window to the time domain to generate the corresponding background benchmarked second time window of acoustic signal data.

8. The method of any one of claims 3 to 7, comprising:

benchmarking the second time window of acoustic signal data with respect to background acoustic signal data characterising the pipeline supply network to generate a corresponding background benchmarked second time window of acoustic signal data; and

determining the anomaly measure for the background benchmarked second time window of acoustic signal data.

9. The method of any one of claims 1 to 8, further comprising on determining that the background benchmarked first time window of acoustic signal data does not indicate the presence of the structural anomaly then supplementing the background acoustic signal data with the first time window of acoustic signal data to further characterise the pipeline supply network.

10. The method of any one of claims 1 to 9, wherein measuring acoustic signal data at the selected location includes measuring at the selected location fluid-borne vibro-acoustic energy transferred by fluid moving through the pipeline supply network to generate fluid-borne acoustic signal data.

11. The method of claim 10, wherein generating the first time window of acoustic signal data includes enhancing the fluid-borne acoustic signal data with other simultaneously measured synchronised acoustic signal data.

12. The method of claim 11, wherein enhancing the fluid-borne acoustic signal data with other simultaneously measured synchronised acoustic signal data includes:

simultaneously measuring environmental vibro-acoustic energy proximal to the selected location to generate synchronised environmental acoustic signal data; and

processing the fluid-borne acoustic signal data to remove from the fluid-borne acoustic signal data, a coherent acoustic signal present in both the fluid-borne and the synchronised environmental acoustic signal data for the time window.

13. The method of claim 12, wherein processing the fluid-borne acoustic signal to remove the coherent acoustic signal includes adaptively filtering the fluid-borne acoustic signal data with respect to the synchronised environmental acoustic signal data by a LMS filter that seeks to minimise an error between an output signal and a desired signal comprising the fluid-borne acoustic signal data.

14. The method of claim 12, wherein processing the fluid-borne acoustic signal to remove the coherent acoustic signal includes determining a non-coherent output power of the fluid-borne acoustic signal data with respect to synchronised environmental acoustic signal data.

15. The method of any one of claims 12 to 14, wherein simultaneously measuring environmental vibro-acoustic energy proximal to the selected location includes simultaneously measuring air-borne vibro-acoustic energy in the space proximal to the selected location to generate synchronised environmental acoustic signal data comprising air-borne acoustic signal data.

16. The method of any one of claims 12 to 14, wherein simultaneously measuring environmental vibro-acoustic energy proximal to the selected location includes simultaneously measuring ground-borne vibro-acoustic energy in the ground proximal to the selected location to generate synchronised environmental acoustic signal data comprising ground-borne acoustic signal data.

17. The method of claim 11, wherein enhancing the fluid-borne acoustic signal data with other simultaneously measured acoustic signal data includes:

simultaneously measuring fluid-borne vibro-acoustic energy at a different location to the selected location to generate synchronised additional fluid-borne acoustic signal data; and

processing the fluid-borne acoustic signal to reinforce in the fluid-borne acoustic signal data, a coherent acoustic signal present in both the fluid-borne and synchronised additional fluid-borne acoustic signal data for the time window.

18. The method of claim 17, wherein processing the fluid-borne acoustic signal to reinforce a coherent acoustic signal present in both the fluid-borne and synchronised additional fluid-borne acoustic signal data includes adaptively filtering the fluid-borne acoustic signal data with respect to the synchronised additional fluid-borne acoustic signal data by a LMS filter that seeks to minimise an error between an output signal and a desired signal comprising the fluid-borne acoustic signal data.

19. The method of claim 17, wherein processing the fluid-borne acoustic signal to reinforce the coherent acoustic signal includes determining a coherent output power of the fluid-borne acoustic signal data with respect to synchronised additional fluid-borne acoustic signal data.

20. The method of any one of claims 3 to 15, wherein the first and second time windows of acoustic data are selected from a time when the corresponding background acoustic noise of the pipeline supply network is below a minimum threshold.

21. The method of any one claims 3 to 15, wherein the first and second time windows of acoustic data are selected from acoustic signal data measured at the same time of day.

22. The method of any one of claims 1 to 21, wherein the pipeline supply network comprises a cast iron pipe, and wherein the structural anomaly includes a circumferential or longitudinal crack in the cast iron pipe.

23. The method of any one of claims 1 to 22, further comprising measuring the acoustic signal data at the selected location.

24. A detection system for detecting a structural anomaly in a pipeline supply network, the pipeline supply network configured to supply fluid to multiple receiving locations, comprising:

a sensor network including a plurality of measurement stations for measuring acoustic signal data at plurality of locations in the pipeline supply network;

one or more data processors operatively connected to the sensor network and configured to carry out the method of any one of claim 1 to 22.