CLAIMS

1. A method for inspecting insulated equipment for corrosion under insulation using a portable, dual detection device comprising an infrared detector, a transmitter horn antenna, and a receiver horn antenna, the two horn antennas being operatively connected to a vector network analyzer, a controller having a memory storing instructions in the form of code, and a processor configured by executing the instructions therein, the method comprising:

identifying a location on the insulated equipment that is suspected of corrosion under insulation;

removing a metal jacket surrounding the insulated equipment at the identified location without stripping the insulation from the equipment;

transmitting, with the transmitter horn antenna, microwaves towards the insulated equipment at the identified location, in which the transmitted microwaves provide heating at the identified location;

receiving, with the receiver horn antenna, the transmitted microwaves after reflection of the microwaves off the insulated equipment;

analyzing, with the vector network analyzer, the transmitted and reflected microwaves, in which the step of analyzing comprises determining the length of a signal path of the microwave from the transmitter horn antenna to the receiver horn antenna;

detecting, with the infrared detector, infrared waves emitted from the identified location of the insulated equipment;

developing, with the infrared detector, an image of an inner surface of the insulated equipment underneath the insulation at the identified location based on the detected infrared waves; and

determining, with the processor, based on the analysis of the transmitted and reflected microwaves and the developed image, whether any corrosion under insulation exists at the identified location.

2. A method according to Claim 1, in which the step of analyzing further comprises:

measuring the power of the microwaves at the time of transmission by the transmitting horn antenna and at the time of reception by the receiving horn antenna; and

determining a power difference in the microwaves at the time of transmission versus at the time of reception.

3. A method according to Claim 1, further comprising the step of:

comparing the determined power difference and the length of the signal at the identified location with a power difference and a length of signal for a calibrated reference insulated equipment to determine an amount of wall thickness loss at the identified location.

4. A method according to Claim 1, in which the two horn antennas are maintained at a fixed distance from the identified location on the insulated equipment during the steps of transmitting and receiving.

5. A method according to Claim 1, in which the insulated equipment is a pipe.

6. A method according to Claim 1, in which the transmitting, receiving, and analyzing steps occur substantially simultaneously with the detecting and developing steps.

7. A method according to Claim 1, further comprising the step of:

reinstalling a metal jacket around the insulated equipment at the identified location.

8. A method according to Claim 1, in which the microwaves are radio waves.

9. A method according to Claim 1, in which the microwaves have a frequency in the range of approximately 30 MHz to approximately 300 GHz.

10. A method according to Claim 1, in which the power of the received microwaves is a function of a distance between the transmitter horn antenna and the receiver horn antenna, a frequency of the transmitted microwaves, a power of the transmitter horn antenna, and a gain of the transmitter horn antenna.

11. A method according to Claim 1, in which the developed image of the surface of insulated equipment at the identified location shows the geometry of the inner surface of the insulated equipment underneath the insulation.

12. A portable, dual system for inspecting insulated equipment for corrosion under insulation, the system comprising:

a transmitter horn antenna configured to transmit microwaves toward the insulated equipment at a selected location on the insulated equipment;

a receiver horn antenna configured to receive the transmitted microwaves after reflection from the insulated equipment at the selected location;

a vector network analyzer operatively connected to the transmitter and receiver horn antennas, in which the vector network analyzer is configured to analyze the power of the transmitted and received microwaves and to determine the length of a signal path of the microwaves from the transmitter horn antenna to the receiver horn antenna;

an infrared detector configured to detect infrared waves emitted from the insulated equipment and to develop an image of the inner surface of the insulated equipment at the selected location based on the detected infrared waves; and

a controller having a memory storing instructions in the form of code, and a processor configured by executing the instructions therein,

in which the controller is configured to enable operations of the transmitter and receiver horn antennas, the vector network analyzer, and the infrared detector.

13. A system according to Claim 12, in which the transmitter and receiver horn antennas are operatively connected to the vector network analyzer via waveguide cables.

14. A system according to Claim 12, in which the vector network analyzer comprises a directional coupler, in which the directional coupler is configured to focus the transmitted microwaves at the selected location.

15. A system according to Claim 12, further comprising:

a time-of-flight microwave camera configured to capture microwaves in flight from the transmitter horn antenna and develop time-resolved imaging and/or 3D imaging based on the captured microwaves.

16. A system according to Claim 12, further comprising:

a scanning holder operatively connected to the transmitter and receiver horn antennas, and configured to maintain the transmitter and receiving horn antennas at respective fixed distances from the selected location.

17. A system according to Claim 12, in which the system components are housed on an unmanned aerial vehicle (UAV).

18. A system according to Claim 17, in which the UAV comprises a rangefinder configured to measure the depth of the UAV and maintain the UAV at a fixed position relative to the selected location.

19. A system according to Claim 12, in which the insulated equipment is a pipe.

20. A system according to Claim 12, in which the microwaves are radio waves.

21. A system according to Claim 12, in which the microwaves have a frequency in the range of approximately 30 MHz to approximately 300 GHz.

22. A system according to Claim 12, in which the transmitting and receiving horn antennas are aligned to face one another to form a line-of-sight configuration, and in which the vector network analyzer is configured to perform free space dielectric measurements on the insulated equipment at the selected location.