J. Condensed Matter Nucl. Sci. 38 (2024) 171–178

Research Article

Impedance Spectroscopy Distinguishes Active ZrO_2-PdNiD NANOR®-type LANR Components

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Abstract

Dielectric/Impedance spectroscopy is an important nondestructive means of measuring the electrical properties of LANR materials and components as a function of frequency. An applied electric field intensity is applied to the material causing its electrical polarization. During a "relaxation" phase, the material's electrical dipoles, atoms, and electrons, all rearrange to align with the applied electrical field. The key is to de-convolve the material response, and then resolve which mechanisms contribute to polarization.

Keywords: Impedance spectroscopy, Dielectric Spectroscopy, Nanor®-type components

1. Introduction: IMPEDANCE- or DIELECTRIC SPECTROSCOPY

Dielectric/Impedance spectroscopy is an important nondestructive means of measuring the electrical properties of LANR materials and components as a function of frequency (Figure 1). An applied electric field intensity is applied to the material causing its electrical polarization. During a "relaxation" phase, the material's electrical dipoles, atoms, and electrons rearrange to align with the applied electrical field. More dielectric mechanisms add in, and are picked up, as the frequency decreases (Figure 2).

Impedance is Complex

- The actual response of any material to an applied electric field intensity is very complex (Figures 2 and 3) – and is handled by complex numbers. First, there results in electrical polarization as the charges move over some distance, and there may be many types.
- Second, there may actually be an energy-absorbing component to the response of the material which may store part of the energy delivered. And the polarization creates an electrical current (Figure 2) linked through Hilbert Space).
- Third, the material may convert the force to a new, different force in a new direction (like a gyroscope responding to a one-directional thrust).

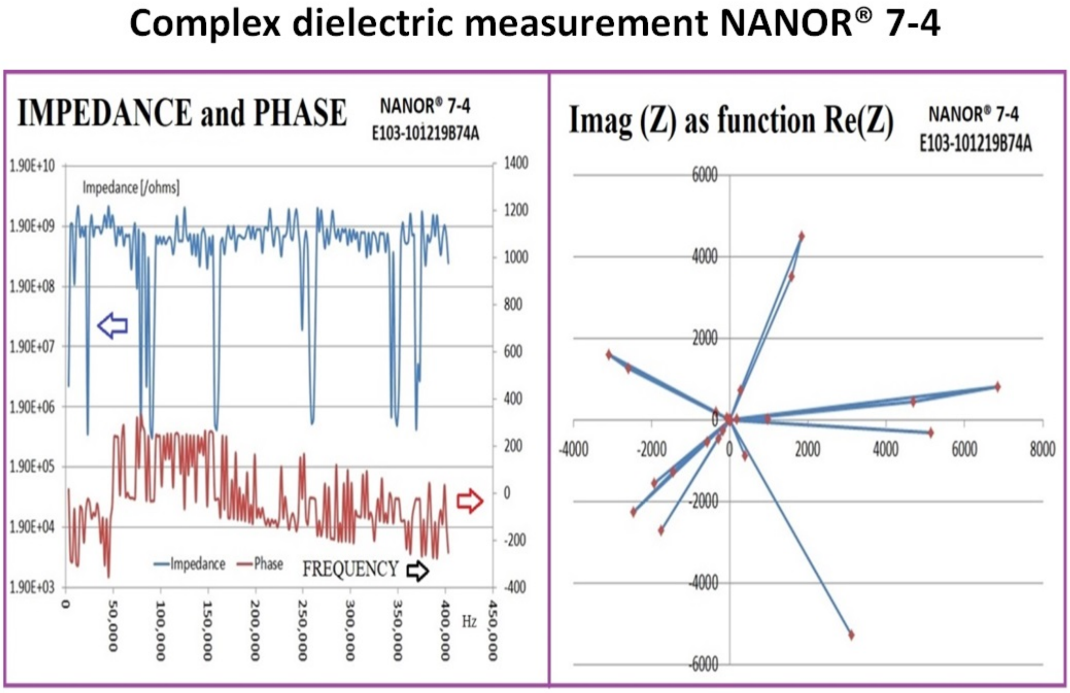


Figure 1. Dielectric Measurements of a NANOR®–type LANR Component Series 7-4. [left] Impedance and phase, as a function of frequency (a Bode plot). [right] Imaginary part of the complex dielectric impedance as a function of the real part of Impedance (Nyquist plot).

- Fourth, in a sinusoidal driving system the flow of electric charges in response to the applied E-field will create a higher-order electric fields resulting from induced (second order) magnetic field intensities. However, at low frequencies, this can be neglected.
- Fifth, in a sinusoidal driving system a phase lag results with additional impact.
- Sixth, depending on the materials, solutions, and electrodes, if irregularities are present at an electrode, for example spikes on a cathode surface, then the electric field intensity distribution can change dramatically with tens of thousands of volts per centimeter appearing over, or near, such irregularities. This has great impact. The calculated applied electric field may not be that which exists in the sample because of this and activation and concentration (space charge) polarizations and double layers, and the possible generation of bubbles (decreasing both the electrode area and adding a low dielectric constant, insulating, layer in front of the critical electrode).

2. Experimental: Presentation(s) of DIELECTRIC DATA

Dielectric data is complex (Figure 3), and can be plotted a number of ways; and all are interrelated, like a shadow to a solid object (Figure 4).

In the Bode plot, the real and imaginary components of the complex impedance, are plotted as a function of log frequency. The projection of the Bode Plot onto the k’ and k” plane is the Nyquist plot. Consistent with the projection

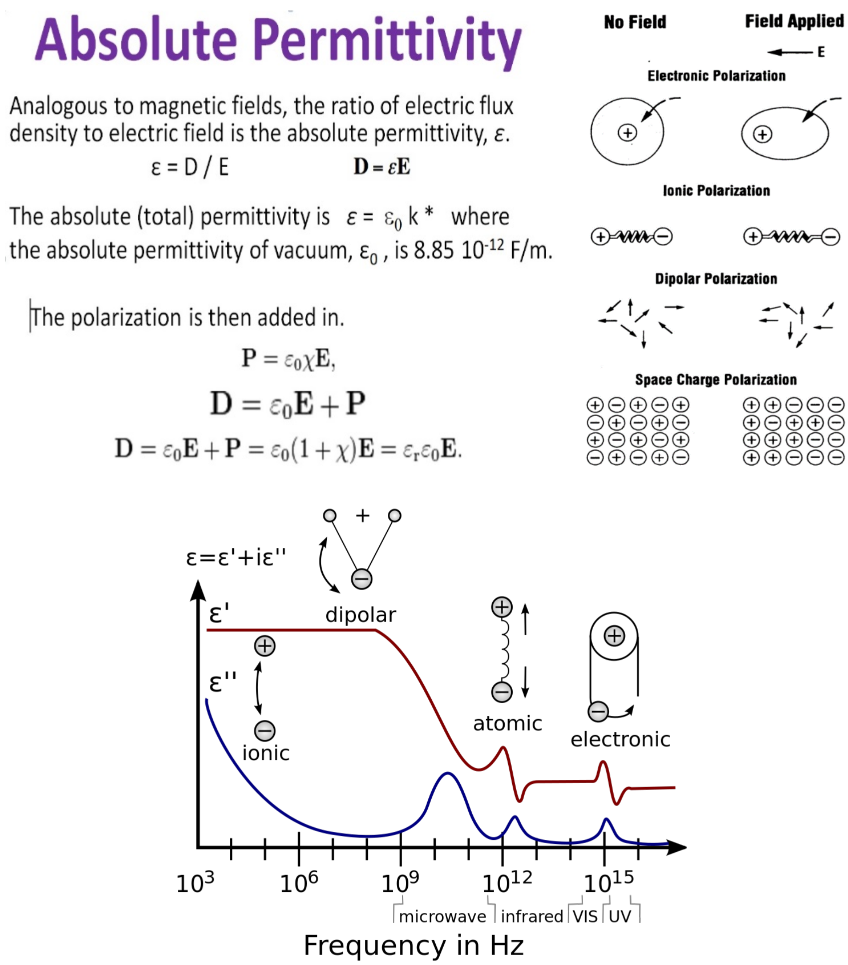


Figure 2. Dielectric Spectroscopy Examines Materials for their Polarizations. The data in Impedance Spectroscopy is presented as the "complex permittivity" which is the dielectric 'constant' and the electrical conductivity as a function of frequency.

of the Bode Plot, in the Nyquist plot, the low frequency data is on the right side of the plot, and the high frequency data is on the left. The Nyquist plot is (generally) a semicircle when the material is characterized by a single time constant.

The projection of the Bode Plot onto the k" (related to electrical conduction, or polarization loss) vs frequency plane is the Cole-Cole plot. The Cole–Cole plot is often used to examine dielectric relaxation in polymer chemistry.

3. Experimental: Impedance Analysis Using AD5933

This is how to measure this using available hardware (Figure 5). AD5933 circuit boards enable mid to high frequency analysis. It is a 12-bit impedance converter ["Network Analyzer"] with a Cortex M3 Core [programmable output to ∼400 kHz with frequency control by I2C interface]. The frequency resolution is <0.1 Hz [2^7 bits], with a phase measurement accuracy ∼0.5%, over a testing impedance range is ∼kΩ to 10 MΩ.

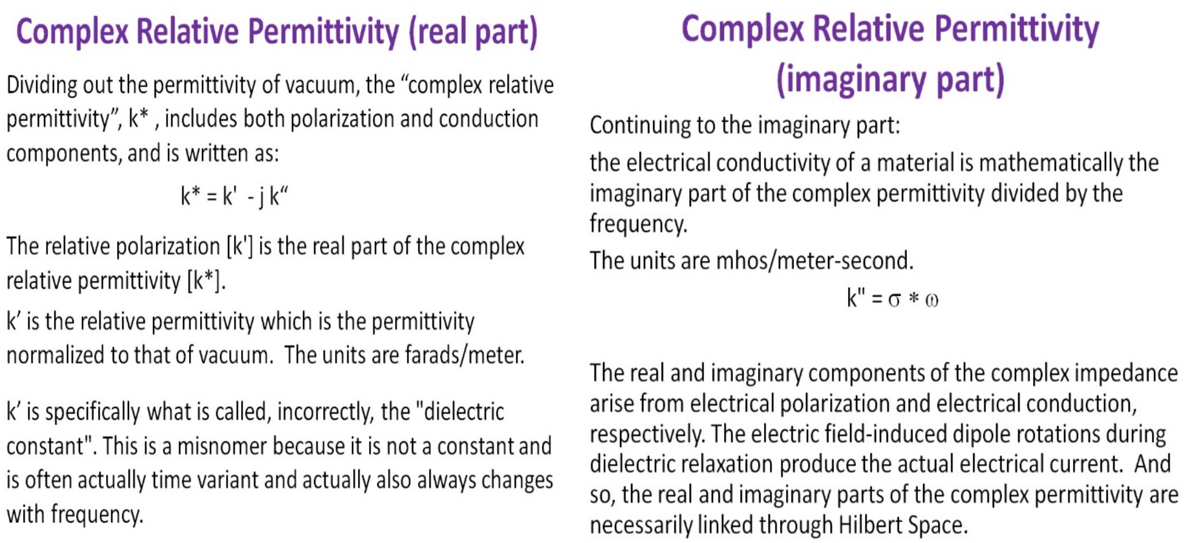


Figure 3. Dielectric Spectroscopy uses Complex Numbers. The data in Impedance Spectroscopy is presented as the "complex permittivity" which is the dielectric 'constant' and the electrical conductivity as a function of frequency.

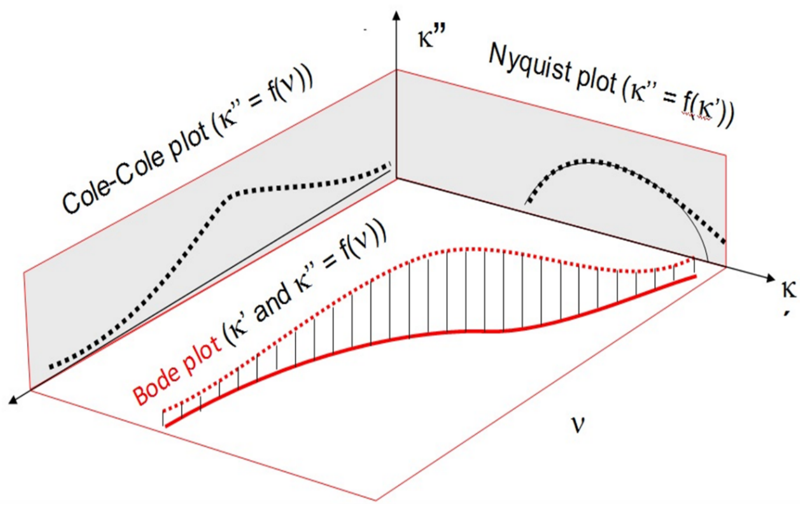


Figure 4. Phase Space of Dielectric/Impedance Spectroscopy. Impedance is complex with both real and imaginary parts. There are several different ways of viewing impedance data. The figure is adopted from, and redrawn from, http://www.gamry.com/App_Notes/EIS_Primer/EIS_Primer.htm.

4. Results: Dielectric Measurements of 3 NANOR®–type LANR Components

Impedance spectroscopy is complex with both real and imaginary parts. There are several different ways of viewing impedance data. In Figure 1 are the Dielectric Results of NANOR® –type Component 7-4. On the left is the Impedance

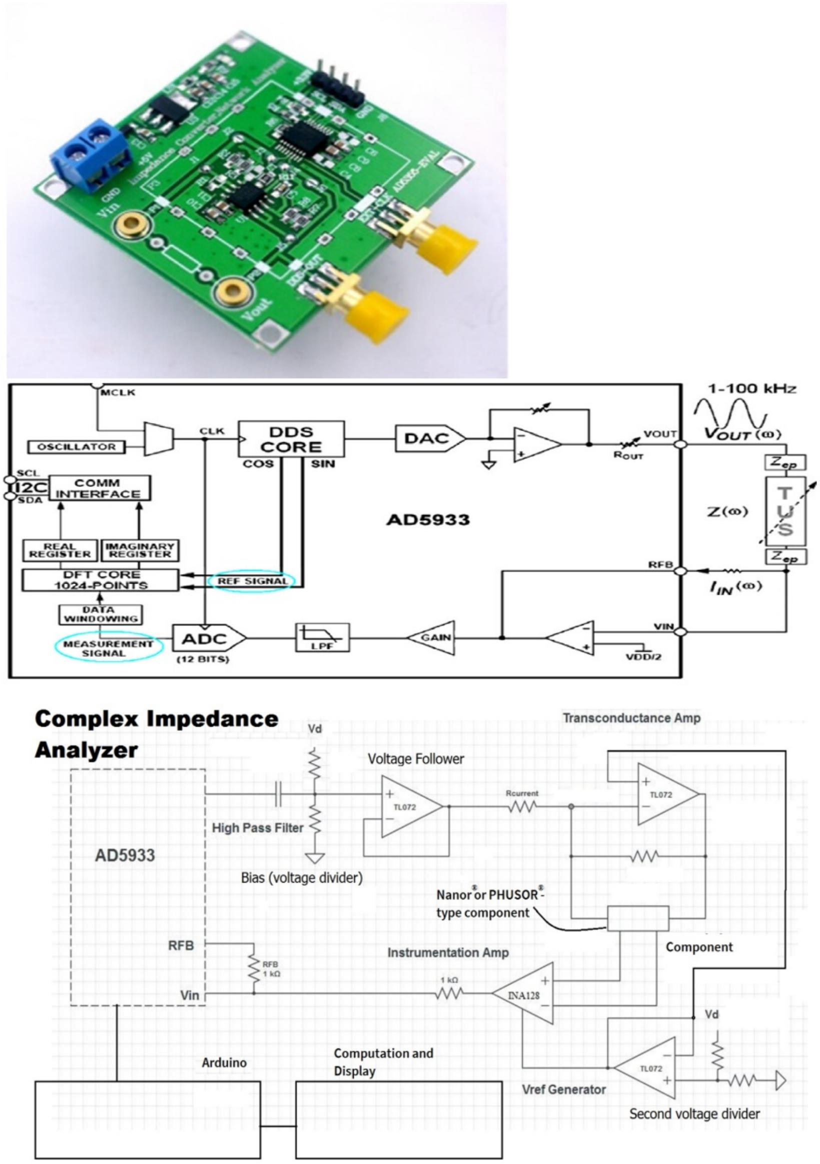


Figure 5. Inexpensive Hardware to investigate Impedance Spectroscopy. Impedance is complex with both real and imaginary parts. There are several different ways of viewing impedance data. It is made easier with available hardware and modifications. The external circuit used created a four-terminal biased and amplified front-end, connected by 12C to an Arduino microprocessor. The output is biased, and then drives an electrical current source. Constant current is sent through the component, while a four terminal conductivity measurement is first sent through an INA128 Instrumentation Amplifier before returning to the AD5933 chip for analysis by a built-in discrete Fourier transform (DFT) module. Arduino software correct quadrature errors.

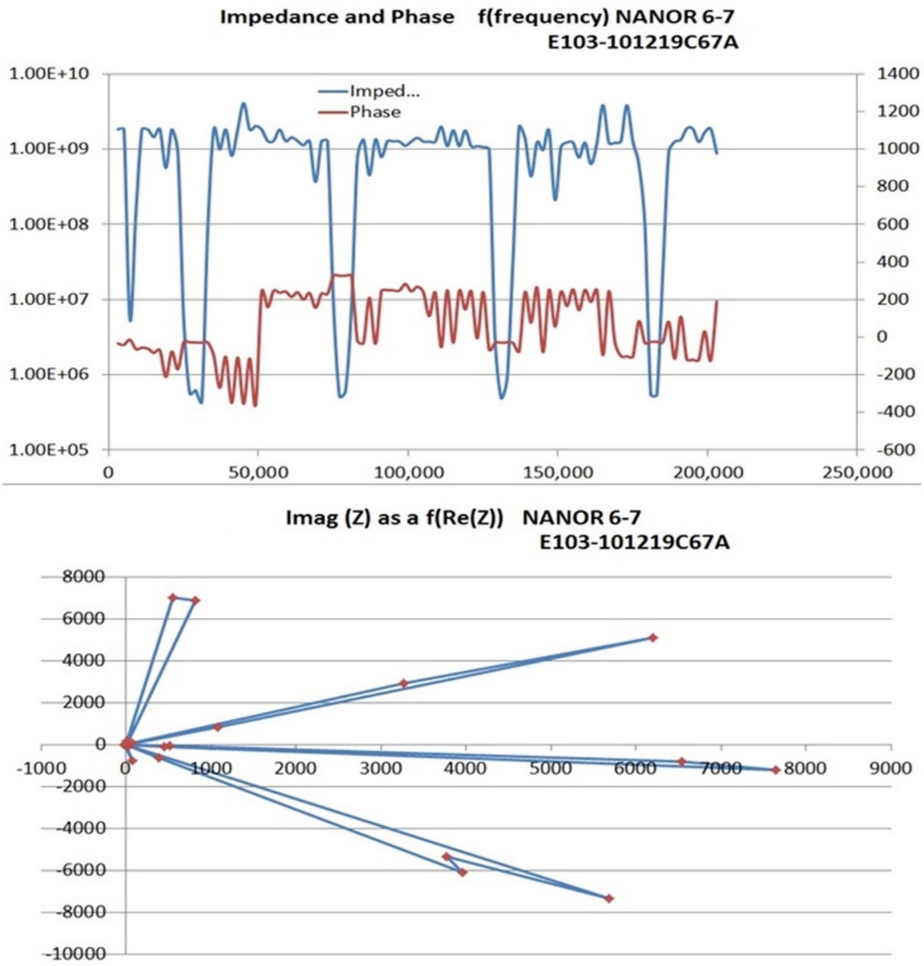
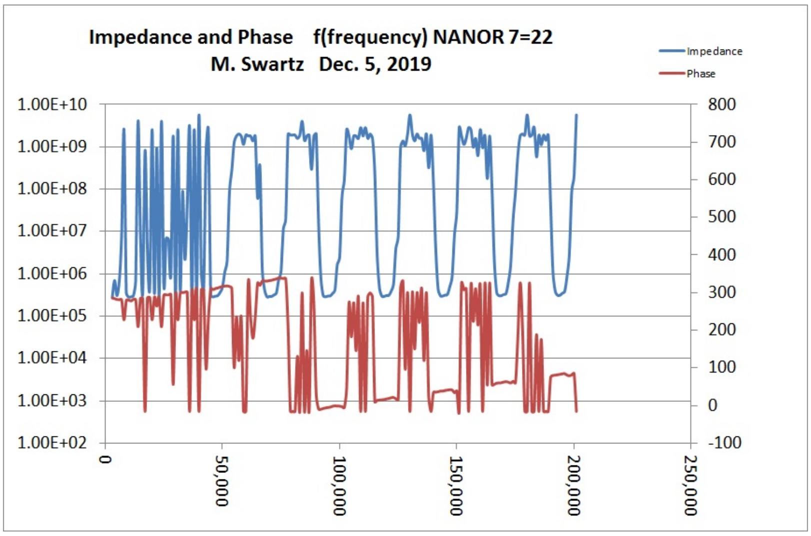


Figure 6. Dielectric Results of NANOR®–type Component Series6-7. Impedance is complex with both real and imaginary parts. There are several different ways of viewing impedance data. [above] Impedance and phase, as a function of frequency (a Bode plot). [below] Imaginary part of the complex dielectric impedance as a function of the real part of Impedance

and phase, as a function of frequency (a Bode plot). On the right is the Imaginary part of the complex dielectric impedance as a function of the real part of Impedance (Nyquist plot).

In Figure 6 are shown the Dielectric Results of NANOR® –type Component 6-7. On the top is the Impedance and phase, as a function of frequency (a Bode plot). On the bottom is the Imaginary part of the complex dielectric impedance as a function of the real part of Impedance (Nyquist plot).

In Figure 7 are shown the Dielectric Results of NANOR® –type Component 7-22. On the top is the Impedance and phase, as a function of frequency (a Bode plot). On the bottom is the Imaginary part of the complex dielectric impedance as a function of the real part of Impedance (Nyquist plot).



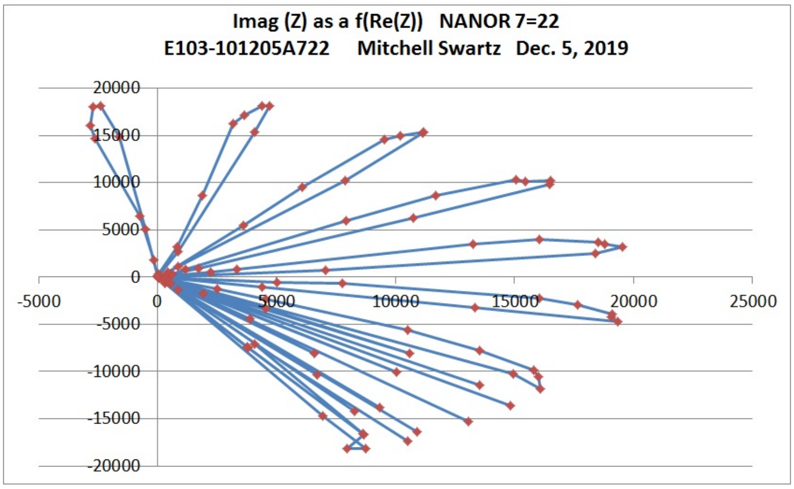


Figure 7. Dielectric Results of NANOR®–type Component Series 7-22. [above] Impedance and phase, as a function of frequency (a Bode plot). . [below] Imaginary part of the complex dielectric impedance as a function of the real part of Impedance (Nyquist plot).

5. Conclusions

5.1. Complex Impedance Measurements of NANOR®-type Components

- Active nanomaterial LANR materials have highly unusual electrical transconduction properties that accompany their excess-heat producing active states. Of particular interest and concern is that dry, preloaded nanomaterials exhibit avalanche electrical breakdown from their active XSH-producing modes which terminates the desired excess heat.

- Previously active dry preloaded LANR nanomaterial components (ZrO_2-PdD and ZrO_2-PdNiD NANOR®-type components) were examined by impedance (dielectric) spectroscopy [$\sim 10^{-4}$ Hz to ~ 2 GHz].
- The Bode, Cole-Cole, Nyquist, and Smith-chart plots of the preloaded LANR NANOR®-type components reveal complex, and quite distinguishable, differences compared to conventional materials and ohmic controls.
- These patterns may result from many reasons including the electrical avalanches seen, and possible synchronized interactions between the loaded deuterons in vacancies, and other reasons ranging from material science to coupling and the transmission line.

Acknowledgments

The author wishes to thank Gayle Verner, Alex Frank, Andrew Meulenberg, Michael Staker, Isidor Straus, David Nagel, John Wallace, Brian Ahern, Jeff Driscoll, Peter Hagelstein, for their editorial assistance, suggestions and support, and JET Energy, Incorporated for contributing to this effort.

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