AN 17–CureView Material Properties Parameters

Introduction

Raw gain-phase data measured by CureView and the LT-451 or LTF-631 Dielectric Cure Monitors is converted to the dielectric properties of permittivity (ε') and loss factor (ε"). Loss factor, however, has two components—an AC component arising from dipole rotation and a DC component caused by the motion of free ions and charge carriers. DC loss factor in turn is converted into ion viscosity (resistivity ρ), which is strongly correlated to physical viscosity in most curing systems and also indicates the cure state of the Material Under Test.

Material Properties are adjustable parameters used to extract the DC component of loss factor for conversion to ion viscosity. Only derived data such as ion viscosity and resistivity are modified through the use of these material properties. The raw data is always preserved unchanged, allowing trial and error adjustment of the material properties to obtain the most useful results.

Accessing the *Material Properties* window

To view and change the ***Material Properties*** used for data processing, click on the "Data Parameters" option under "Edit" on the main menu bar as shown below:

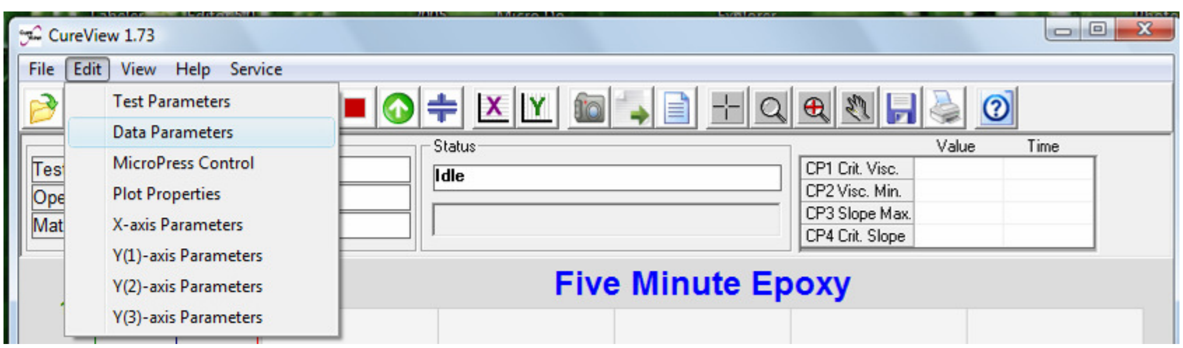

Figure 1
Main menu bar

The ***Material Properties*** window will appear.

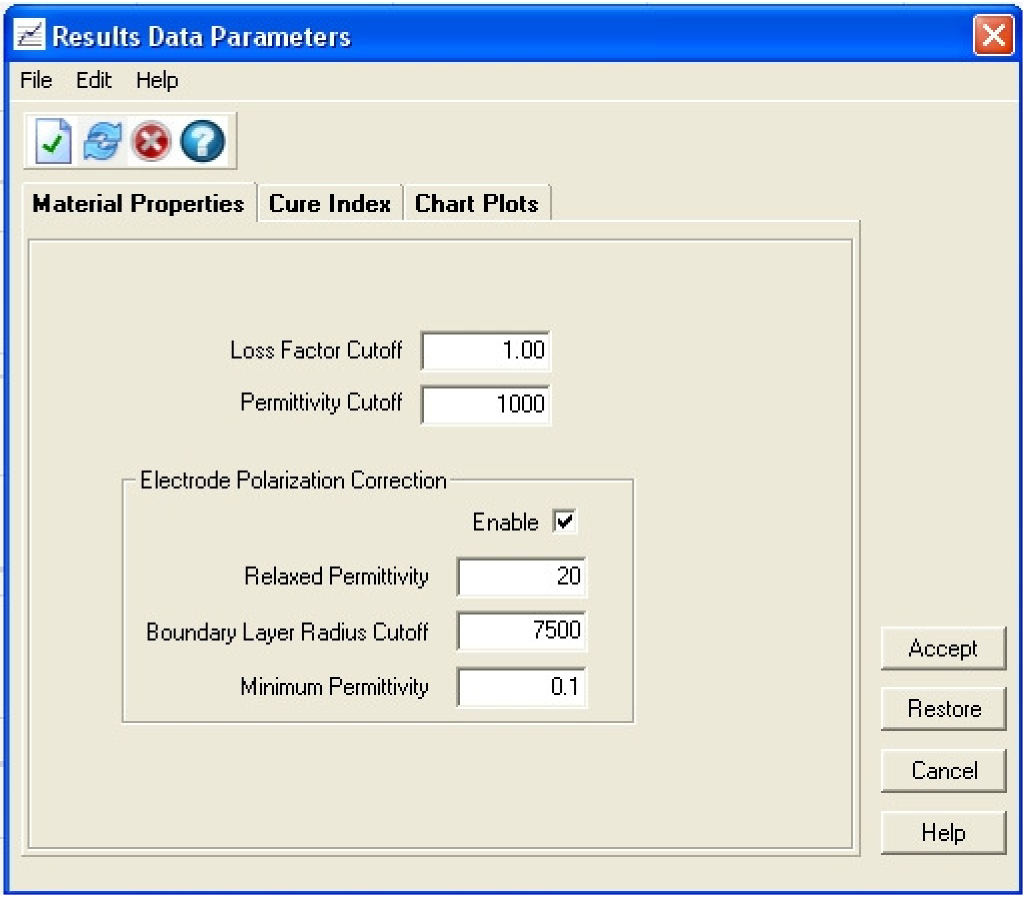

Figure 2
***Material Properties* window**

The Material Properties used when analyzing dielectric data are defined as follows:

Loss Factor Cutoff

Function: Prevents conversion of loss factor (ε”) data to ion viscosity when ε” < Loss Factor Cutoff.

Default: 5 in linear loss factor units.

Loss Factor Cutoff is sometimes also called *Dipole Cutoff*. CureView assumes that dipole rotation and the AC component of loss factor dominate the dielectric response when ε” < Loss Factor Cutoff. Calculation of ion viscosity would produce misleading results under these conditions.

Figure 3 shows an example of multiple, non-overlapping ion viscosity curves (green traces) when the Loss Factor Cutoff is too low. In this case, the ion viscosity data is confusing because they are derived from both the AC and DC components of loss factor. The data do not give a clear indication of which curve—if any—corresponds to physical viscosity and the state of cure.

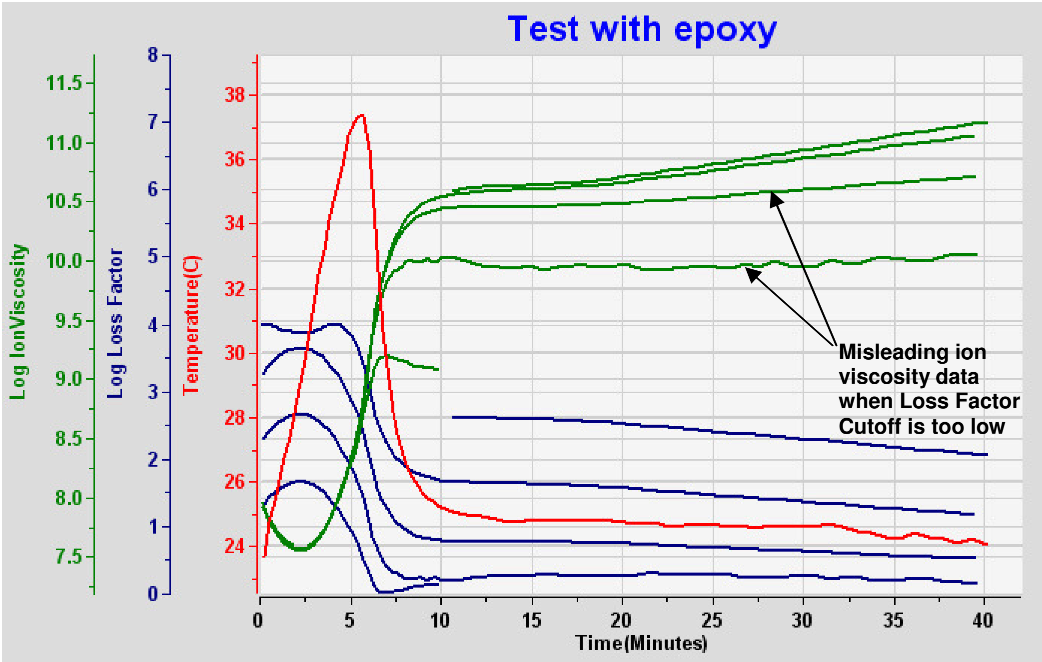

Figure 3
Plot showing ion viscosity data when Loss Factor Cutoff is too low

Results with a higher Loss Factor Cutoff are shown in Figure 4.

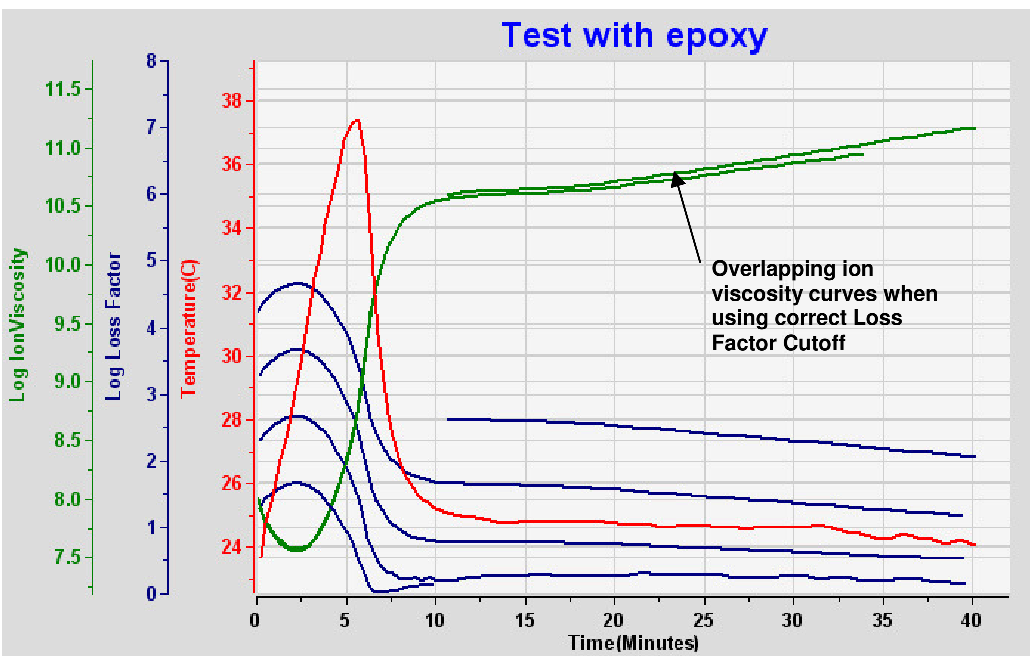

Figure 4
Plot showing ion viscosity with correct Loss Factor Cutoff

Note that in Figure 4 the plotted ion viscosity curves overlap, indicating that the presented dielectric data is dominated by the DC component of loss factor. This result displays only information that correlates with physical viscosity and the cure state of the material under test.

Figure 5 shows another example of dielectric data where the Loss Factor Cutoff is too low. In this case the Loss Factor Cutoff = 5. Consequently, CureView only calculates ion viscosity when the loss factor data is greater than 5. In Figure 5 ion viscosity is plotted on a logarithmic scale, so ion viscosity is calculated only if log(loss factor) is greater than log(5).

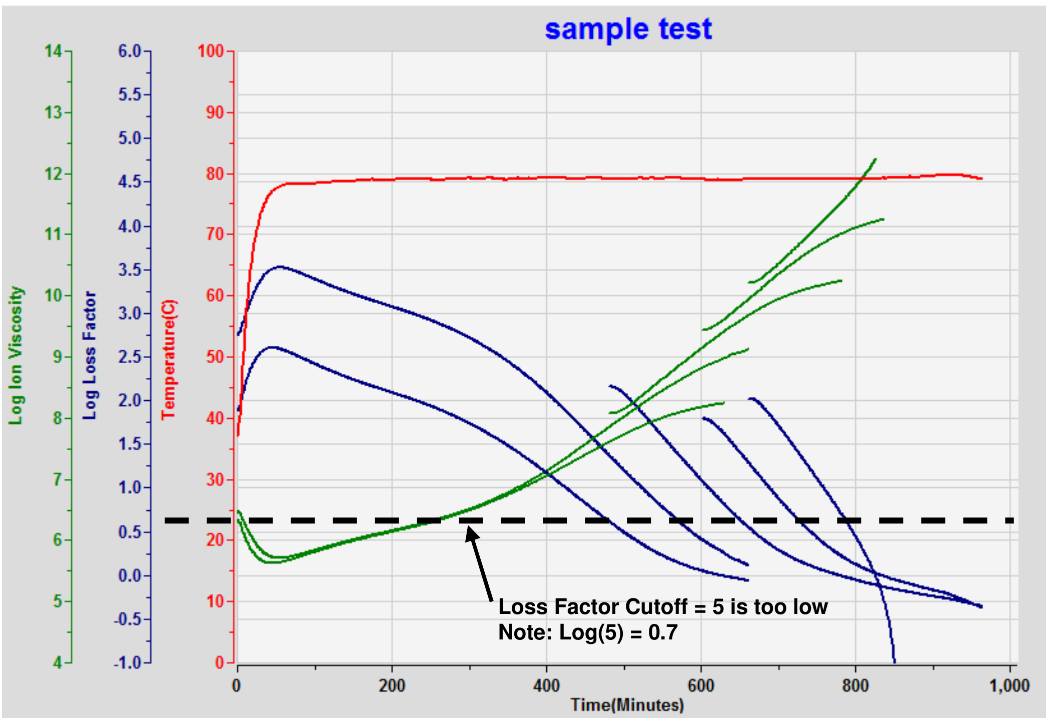

Figure 5
Plot showing ion viscosity data when Loss Factor Cutoff = 5 is too low
(Only Log Loss factor data greater than log(5) is converted to Log Ion Viscosity)

Figure 5 shows that multiple, diverging ion viscosity curves result when the Loss Factor Cutoff is too low. These curves appear because AC conductivity dominates ion viscosity at the lowest plottted values. To eliminate these multiple curves, the Loss Factor Cutoff must be increased to allow calculation of ion viscosity only when DC conductivity dominates.

Figure 6 shows the result when the Loss Factor Cutoff is at the correct value. In this case the Loss Factor Cutoff = 10. CureView then plots ion viscosity only when the loss factor is greater than 10. In this case the diverging ion viscosity curves disappear.

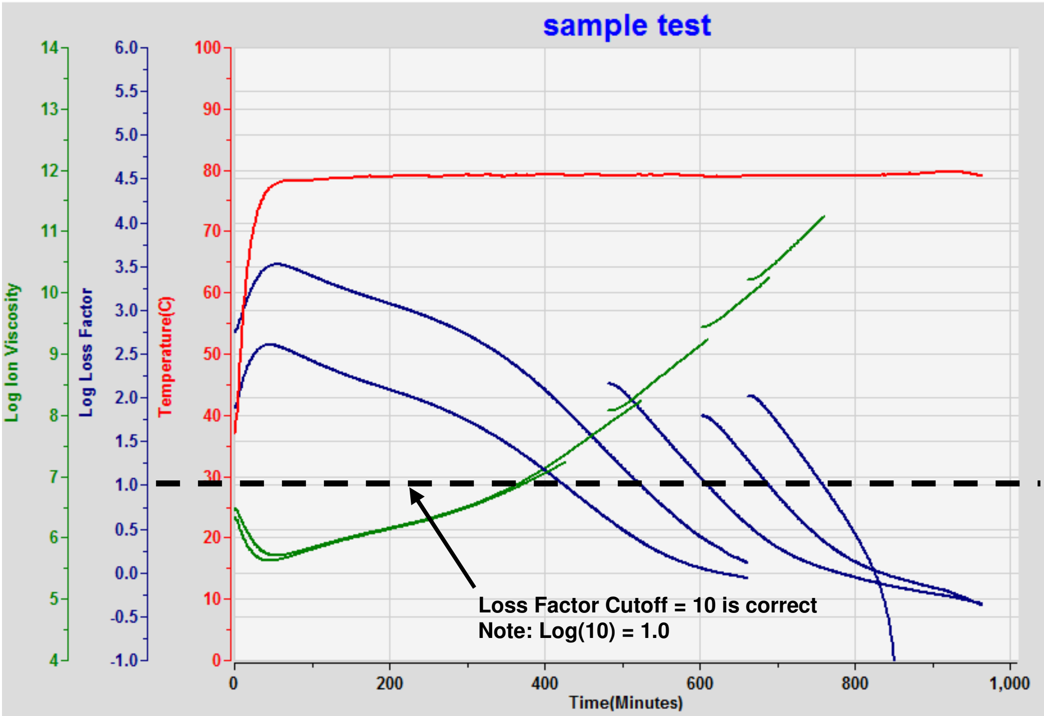

Figure 6
Plot showing ion viscosity with Loss Factor Cutoff = 10
(Only Log Loss factor data greater than log(10) is converted to Log Ion Viscosity)

The correct value of Loss Factor Cutoff results in a family of curves that trace the ion viscosity and the cure of the material from start to finish. To determine a good value for Loss Factor Cutoff:

- Increase the Loss Factor Cutoff to eliminate ion viscosity curves that do not overlap.
- Decrease the Loss Factor Cutoff if ion viscosity curves are missing or have large gaps.

Permittivity Cutoff

Function: Prevents loss factor (ε”) data from being converted to ion viscosity when ε’ > Permittivity Cutoff.

Default: 1000 in linear permittivity units.

CureView assumes that electrode polarization affects the dielectric response when the measured permittivity is very high, causing loss factor to appear artificially low. Under these conditions the conversion of loss factor to ion viscosity would produce erroneous results. To prevent the plotting of misleading data, CureView does not calculate ion viscosity when ε’ > Permittivity Cutoff.

If the value of Permittivity Cutoff is too low, then useful ion viscosity data is not displayed. If the value of Permittivity Cutoff is too high, then the calculated ion viscosity data includes distortions caused by electrode polarization. Figure 7 shows the deletion of valid ion viscosity data at the beginning of cure as a result of a Permittivity Cutoff that is too low.

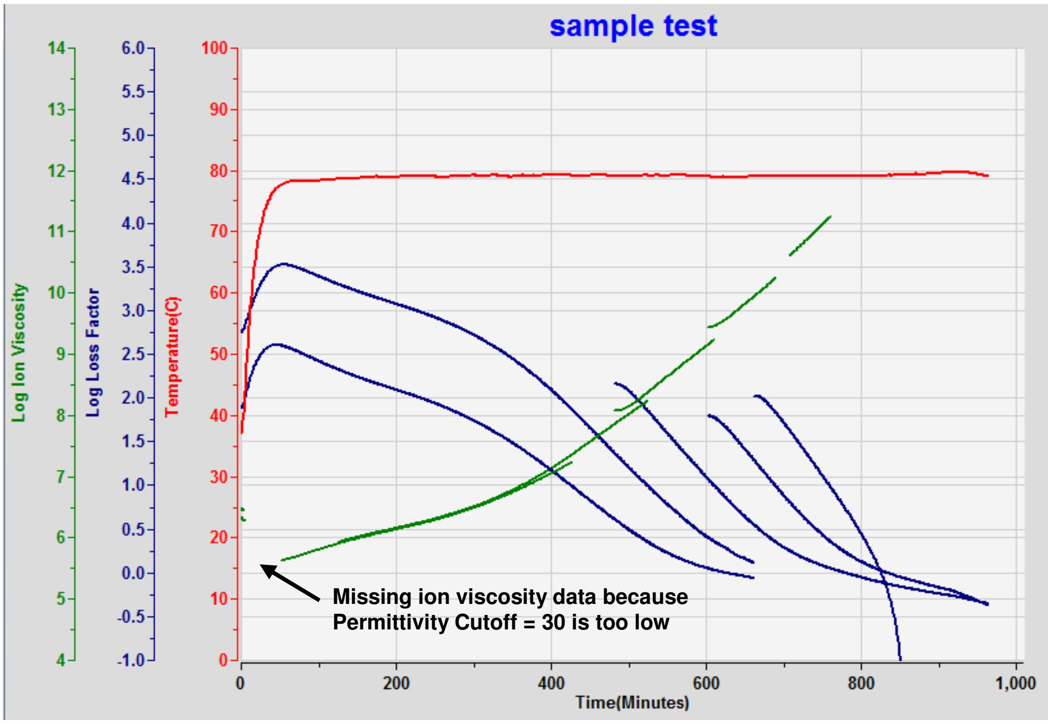

Figure 7
Plot of ion viscosity with Permittivity Cutoff = 30

Figure 8 shows the same data with the Permittivity Cutoff adjusted to a value of 100. In this case the ion viscosity is correctly calculated at the beginning of cure and is displayed, making it possible to follow the progress of ion viscosity from beginning to end. To determine a good value for Permittivity Cutoff:

- Increase the Permittivity Cutoff to restore ion viscosity data missing from the beginning of cure.
- Decrease the Permittivity Cutoff if ion viscosity curves show electrode polarization at the beginning of cure (See following section about electrode polarization).

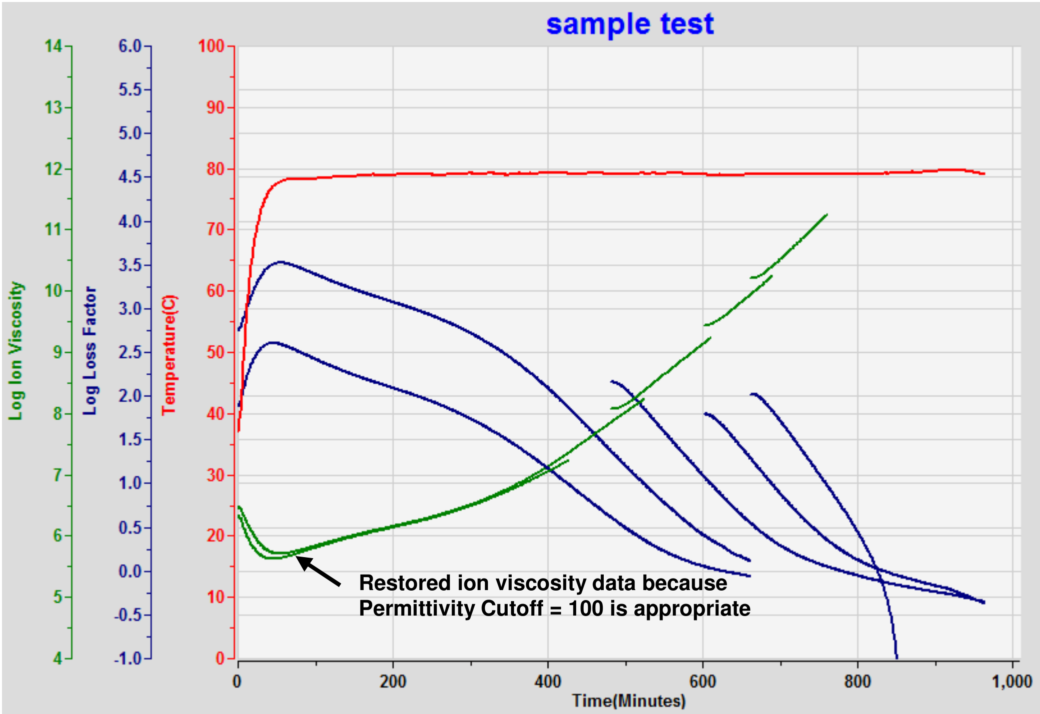

Figure 8
Plot of ion viscosity with Permittivity Cutoff = 100

Electrode Polarization Correction

Electrode polarization occurs when the Material Under Test is both highly fluid and highly conductive, causing the formation of an insulating boundary layer on the surface of the sensor electrodes. This boundary layer can distort the loss factor data as shown in Figure 9. CureView can correct the effect of electrode polarization with proper selection of material properties.

Clicking to insert a check (√) in the "Enable" checkbox causes CureView to correct the effect of electrode polarization. A blank in the "Enable" checkbox results in no correction for electrode polarization. Due to the need to determine the material properties by trial and error, electrode polarization correction is normally used during replotting and analysis and not during real time data acquisition.

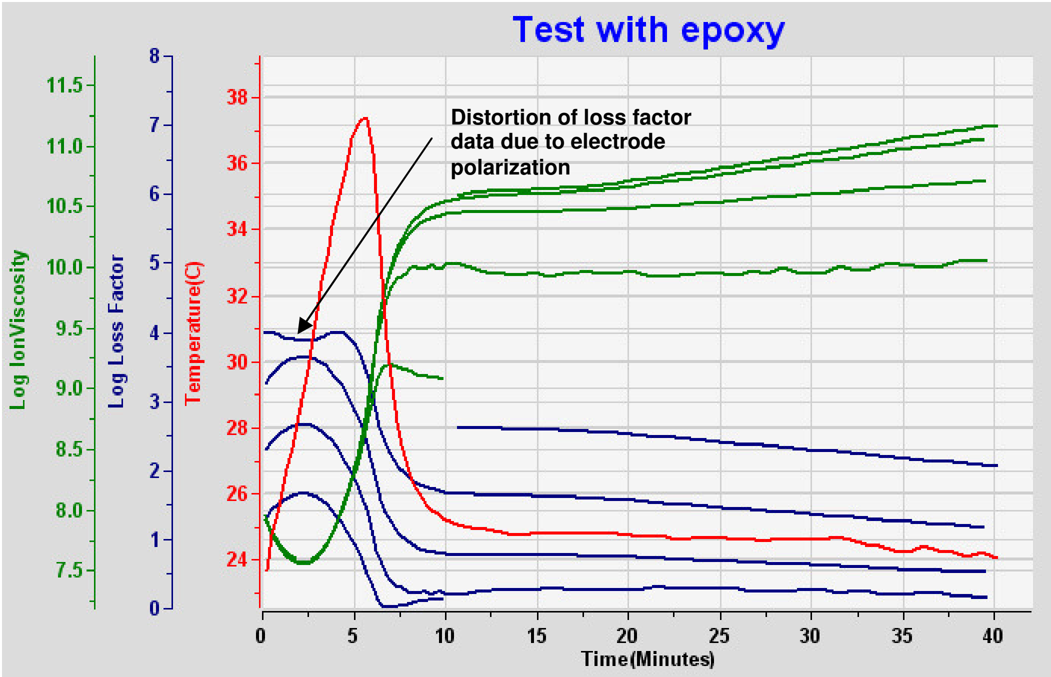

Figure 9
Plot showing distortion of loss factor due to electrode polarization

The material parameters affecting electrode polarization correction are defined below:

Relaxed Permittivity

Definition: The permittivity of the Material Under Test toward the end of cure. For most polymers it is in the range of 4 to 10.

Default: 10 in linear permittivity units.

Boundary Layer Radius Cutoff

Definition: The lower limit of permittivity used for boundary layer correction.
Default: 25 in linear permittivity units.

Electrode polarization distorts dielectric data by artificially increasing permittivity (ε') and decreasing loss factor (ε") under conditions of both high fluidity and high conductivity. When plotted against time, loss factor curves may display anomalous behavior as shown previously in Figure 9.

A Cole-Cole plot of loss factor against permittivity on linear scales is typically semi-circular when data is distorted in this way, as shown in Figure 10. The Boundary Layer Radius Cutoff determines when to apply or not apply boundary layer correction.

The default value for Boundary Layer Radius Cutoff is 25. For purposes of electrode polarization correction, the exact value of the Boundary Layer Radius Cutoff is generally not critical, but best results are obtained through trial and error until the corrected loss factor curves appear similar to those of Figure 11.

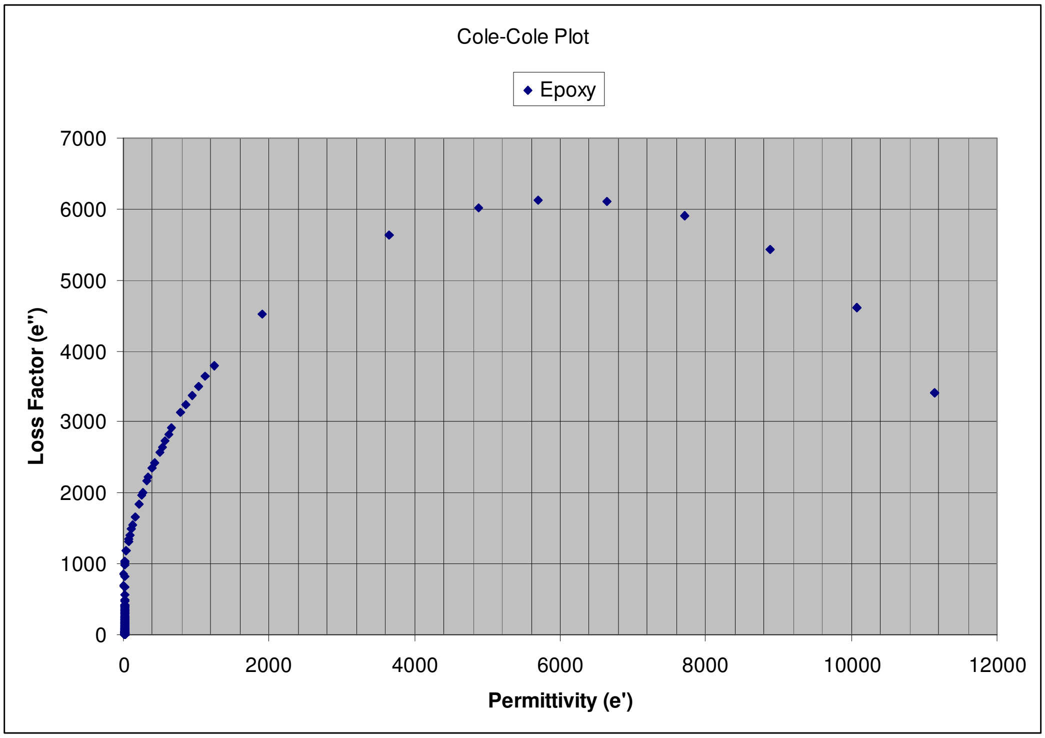

Figure 10
Cole-Cole plot of cure data distorted by electrode polarization

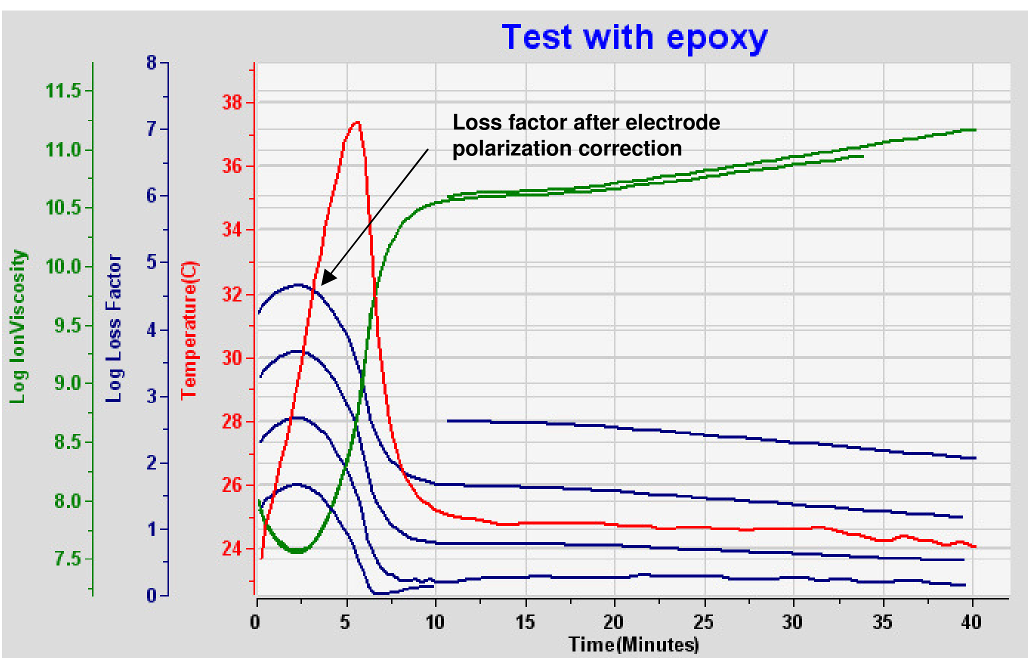

Figure 11
Plot showing data after electrode polarization correction

Minimum Permittivity

Definition: Permittivity below which CureView will not convert the associated loss factor to ion viscosity.

Default: 0.1 in linear permittivity units.

Summary of *Material Properties*

Table 1
Summary of *Material Properties*

Material Property	Action/Description	Default
Loss Factor Cutoff	CureView does not convert data to ion viscosity for loss factors below the Loss Factor Cutoff. Value is in linear units. Loss factors below Cutoff assumed to be dominated by AC conductivity.	5
Permittivity Cutoff	CureView does not convert data to ion viscosity when permittivity is above the Permittivity Cutoff. Value is in linear units. Loss factors assumed to be distorted by electrode polarization when permittivity is above Cutoff.	1000
Relaxed Permittivity	Permittivity of material under test at end of cure.	10
Boundary Layer Radius Cutoff	Low permittivity limit for application of boundary layer correction.	25
Minimum Permittivity	CureView does not convert data to ion viscosity when permittivity is below the Minimum Permittivity.	0.1

Conclusion

Many factors can cause confusing interpretation of dielectric data. Selection of appropriate ***Materials Properties*** directs CureView to process dielectric data to remove artifacts due to the effect of dipoles or electrode polarization. The result, ideally, would be ion viscosity due primarily to DC resistivity (DC conductivity), which correlates strongly with the state of cure of polymeric materials.