much more complicated equipment and procedures compared to the simple comparison technique used for measuring DF.

DF then is a convenient, somewhat artifical method by which the "inefficiency" of a capacitor can be noted.

Q (Factor of Merit)

The "Q" or "Factor of Merit" of a device is also an artifical measurement that will conveniently allow notation ot the "inefficiency" (or power losses) of that device.

By definition, Q is the ratio of the reactance to the series resistance. This then shows the following relationship:

$$Q=\frac{X}{R}=\frac{1}{DF}$$

or: Q is the reciprocal of the DF.

For instance:

$$DF=1.0\% \quad \text{then} \quad Q=\frac{1}{.01}=100$$

Common usage pretty much boils down to this:

1. "Power Factor" is used for capacitors when the PF is 10% or greater.
2. "Dissipation Factor" is used when the PF is less than 10%.
3. "Q" is occasionally used for capacitors. It is widely used for inductors and total ciruits.

TECHNICAL BULLETIN NO. 06

CAPACITORS... DISSIPATION FACTOR

Whenever power (energy) in the form of voltage times current is applied to a capacitor, part of that total power is used or "lost" within the capacitor itself. The ratio of this "power loss" to the total power supplied is the "power factor" (PF) of the capacitor. This PF figure then is a measurement factor for rating the "inefficiency" of the power transfer capabilites of the capacitor.

For those capacitors where the PF figure is .1 (10%) or less, a ratio figure known as the "dissipation factor" (DF) is more commonly used. The reason for this usage of the DF figure is simply a convenience that takes advantage of the fact that DF measurements on a capacitor are much simpler and easier to make on standard capacitance bridges than the determination of PF.

The relationships between PF and DF, and the factors that are concerned in these figures are delineated in the following: (AC voltage applied)

where;

R=equivalent series resistance (ohms)

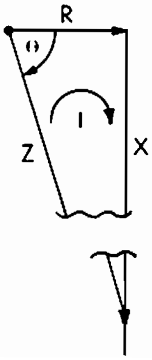
$X=(X_C \cdot X_L)$ = total reactance (ohms)

$X_C=\frac{1}{2\pi fC}$ = capacitive reactance (ohms)

C=capacitance (farads)

f=frequency (Hz)

$X_L=2\pi fL$ = inductive reactance (ohms)



L=inductance (henries)

$Z^2=R^2+X^2$ = impedance (ohms)

I=current (amperes)

θ=phase angle (radians or degrees)

Ohm's Law equations are:

$$E=IZ$$
$$E_X=IX$$
$$E_R=IR$$

where:

E_R=series resistance voltage

E_X=reactance voltage

E – circuit voltage

So: $$PF=\frac{\text{Power Loss}}{\text{Total Power}}=\frac{E_R I}{EI}=\frac{I^2R}{I^2Z}=\frac{R}{Z}=\cos\theta$$

The $\cos\theta$ and $\cot\theta$ approach convergence as θ approaches 90 . At 90 , both $\cos\theta$ and $\cot\theta = 0$ and $Z = X$.

From $\cos\theta = 0$ to $\cos\theta = .1$ (10%), the divergence error of the equation $\cos\theta = \cot\theta$ goes from 0 to .5% error.

∴ For values of $PF = \cos\theta = .1$ (10%) or less, we equate $\cos\theta$ and $\cot\theta$

Thus: $$PF=\cos\theta \simeq \cot\theta = \frac{R}{X} = DF$$

And we see that the "dissipation factor" (DF) is the ratio of the series resistance to the reactance.

In the case of a capacitor, particularly in the low frequency range (30K Hz and below), the X_L term is extremely small compared to X_C and can be ignored for computation purposes. This is best illustrated by the following typical example of a metallized mylar dielectric capacitor:

(shown on next page)

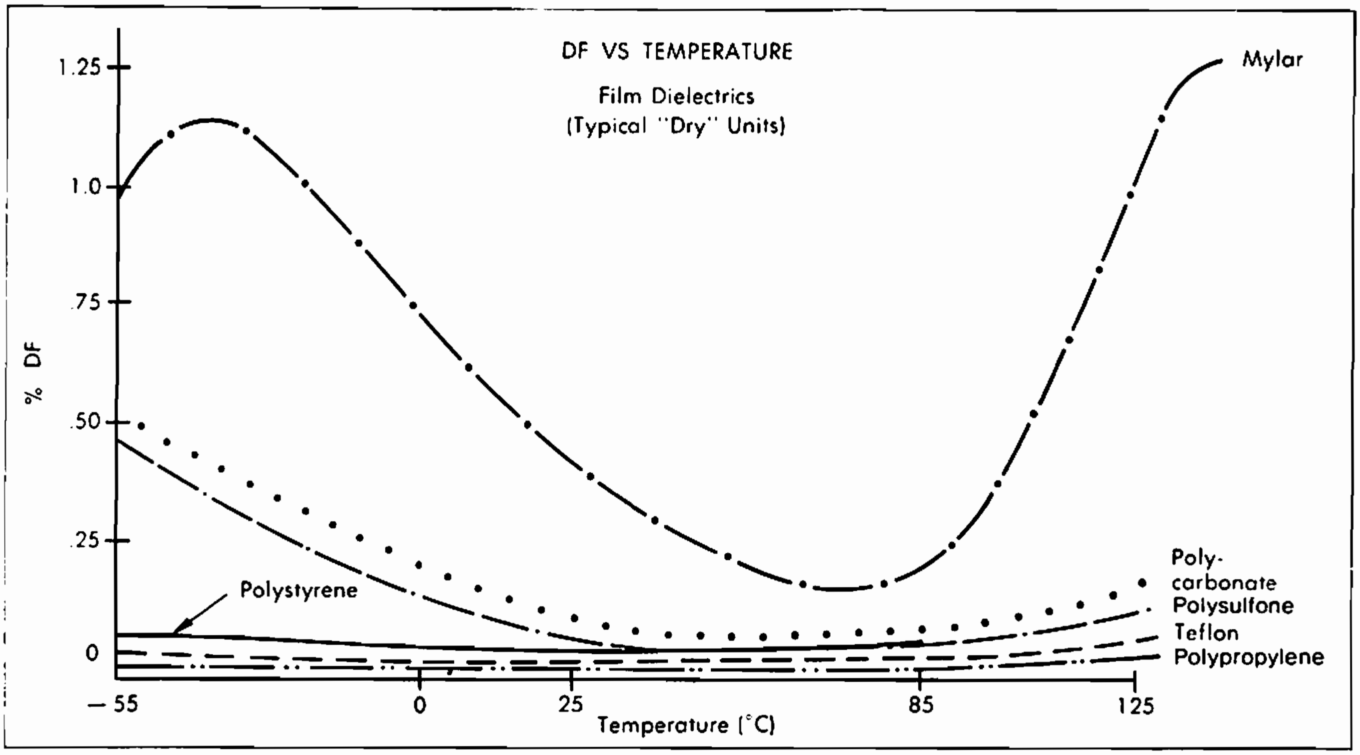


Figure 1

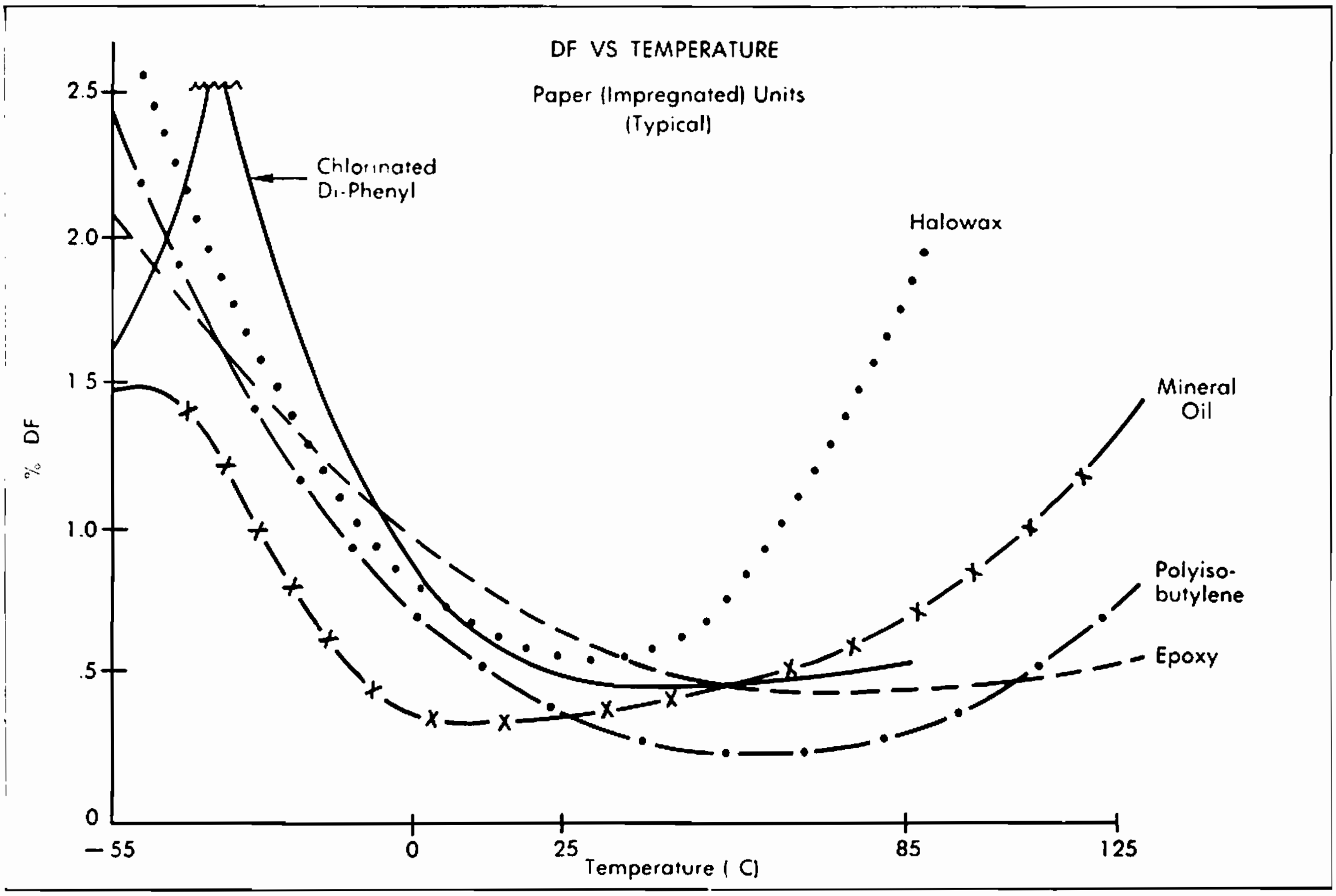


Figure 2

Electrical Measurements: (@ 1000 Hz)

Capacitance = 1.0 mf   Inductance = .03 mh

$$X_C = \frac{1}{2\pi fC} = \frac{1}{(6.28)(10^3)\,10^{-6})} = \frac{10^3}{6.28} = 160 \text{ ohms}$$

$$X_L = 2\pi fL = (6.28)(10^3)\,3\times10^{-8} = .00188 \text{ ohms}$$

$$\therefore \text{DF} = \frac{R}{(X_C - X_L)} \simeq \frac{R}{X_C} = 2\pi fCR$$

And we see that the DF figure will vary with frequency, capacitance, and series resistance. In addition, the DF figure will also vary with whatever environmental conditions cause C and R to change such as temperature, moisture, pressure, etc. Figures 1 and 2 compare the DF vs. Temperature characteristics of some of the commonly used capacitor dielectrics.These plots are average curves and should not be construed as specific or absolute values since special additives, fillers and special procedures can change the curves considerably for individual cases.

Mica and glass dielectric capacitors generally have DF values between .03 to 1.0% DF over the full temperature range.

Ceramic dielectric units can be very stable or extremely erratic depending on the dielectric constant (K) value of the ceramic mixture. NPO type units (low K values) will generally measure between .1 to .5% DF at room temperature, while the General Purpose type (high K values) generally read between 1.0 to 2.5% DF at room temperature. Most electrolytic type capacitors have PF values that exceed 10% and therefore the relation DF=PF is not valid. An exception to this could be the "solid" type tantalum line that will hold between 3.0 to 6.0% PF over the temperature range of −55°C to +85°C. The accurate determination of the DF vs Frequency characteristic of capacitors, particularly at the upper frequency range, is highly influenced by testing equipment and procedures.

Except in a very few special cases where even a few ohms of series resistance becomes critical (extreme cases or discharge times), the value of the DF is of no real importance in the operation of an essentially DC circuit (for example; pure DC or a small AC ripple superimposed on a polarizing DC voltage).

The manufacturer can and does use the DF measurement as a quaility tool. Variations in DF above normal values for a particular line or lot of units would indicate possible loss of control on materials or manufacturing procedures. By monitoring the DF measurements, possible troubles in the production line can be discovered quickly and corrective action instituted before the trouble reaches catastrophic proportions.

For the user who is faced with essentially AC or high frequency pulsing DC applications, the value of the DF is of prime concern since the series resistance factor in DF is the heat producing element in these applications.

TECHNICAL BULLETIN NO. 07

CAPACITORS...AC APPLICATIONS (PART 1)—BEWARE!

Before proceeding to a detailed examination of the capacitor and its reaction to AC and DC voltages, let's discuss some other generalizations that are commonplace in the industry.

1. "As long as the peak value of the RMS voltage does not exceed the DC voltage rating, it's okay for the AC circuit." Only partially true—there are other factors that must be considered and will be covered later.
2. "If I'm getting failures on AC, I can eliminate the failure by using a higher DC voltage rating." Not necessarily true—a higher DC voltage unit may result in a decrease of failures, but will not eliminate them if the cause of the failures remains uncorrected.
3. "Any AC rated unit can be used in an equivalent DC circuit." This is generally true—but the reverse is not!

AC VERSUS DC

The application of a DC voltage to a capacitor results in an electrical force field (voltage gradient) stress on the dielectrics. This stress imposes a plus (+) and minus (−) electrical relationship on the dielectric molecules which in turn must then assume a "dipole" characteristic, and line up directionally with the force field.
(See Figure 1)

During the initial transient (short time) period of charge, electrons move out into the dielectric and initiate this dielectric polarization. As long as the force field remains on the capacitor, these polariza-