PICKING THE PROPER INSULATION

... safety factors are in order ...

Contents

Picking the Proper Insulation .................................................. Page 2
1953 Edison Radio Amateur Award Winner .......................... Page 4
Tweaking the Spectrum .......................................................... Page 7
A Supersized Generator ....................................................... Page 8
It is generally recognized the primary function of electrical insulation is to guide current flow through desired paths and to separate electrical circuits and conductors which operate at different voltages. Furthermore, it is evident there are gross differences in the way insulations perform. For example, cables wound on parapetron forms have a higher “Q” than those wound on molded wood forms; and certain circuits require the use of mica capacitors while in others cheaper paper capacitors will perform satisfactorily. What are the electrical specifications by which the performance of insulations is measured? What considerations are involved in the selection of the proper insulation for a particular application? Some specifications (like power factor) are easily measured and known to a few percent. Others (like puncture strength) are very nebulous and must be used with a great deal of caution in any design application. Liquid and solid materials are broadly divided into classes according to their ability to conduct electricity. To be specific, we may measure the resistance of a number of liquid and solid materials between two metal plates each 1 inch square and separated by 1 inch (see Figure 1). We find (see Table 1) that metals and alloys are relatively good conductors of electricity while mineral oils, glass, wood, rubber and saran are relatively poor conductors. A sample of a sample having the above-mentioned dimensions is called resistivity and is measured by a special instrument called the Megohmmeter.

Between the two extremes (i.e., the conductors and insulators) are a great many classes of insulating materials. Special properties of these insulating materials are desirable, and are measured in terms of such factors as puncture strength, volume resistivity, surface resistivity, and dielectric constant.

### TABLE I

**Insulation Specifications** *(Measured at 25°C)*

<table>
<thead>
<tr>
<th>Material</th>
<th>Resistivity; Dielectric Content, at 25% rel. humidity or lower</th>
<th>Power Factor (% I)</th>
<th>Puncture Strength (d-c or peak-c-c V/In)</th>
<th>Thickness of test sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>60 c/s</td>
<td>1 mc</td>
<td>100 mc</td>
</tr>
<tr>
<td>INORGANIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>air</td>
<td>infinite</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>mica</td>
<td>10⁻⁶</td>
<td>1-7</td>
<td>0.3</td>
<td>0.04</td>
</tr>
<tr>
<td>Myltron</td>
<td>10⁻⁶</td>
<td>7</td>
<td>0.64</td>
<td>0.21</td>
</tr>
<tr>
<td>cellulose</td>
<td>10⁻⁶</td>
<td>6</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>glass (Pyrex)</td>
<td></td>
<td>5</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>baryum titanate</td>
<td></td>
<td>1300</td>
<td>6.0</td>
<td>1.0</td>
</tr>
<tr>
<td>ORGANIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teflon</td>
<td>10⁻⁶</td>
<td>2.1</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>polyethylene</td>
<td></td>
<td>10⁻⁶</td>
<td>2.2</td>
<td>0.01</td>
</tr>
<tr>
<td>polypropylene</td>
<td></td>
<td>10⁻⁶</td>
<td>2.6</td>
<td>0.02</td>
</tr>
<tr>
<td>block Bakelite</td>
<td></td>
<td>10⁻⁶</td>
<td>5</td>
<td>1.0</td>
</tr>
<tr>
<td>Lucite Plexiglass</td>
<td></td>
<td>10⁻⁶</td>
<td>5</td>
<td>6.0</td>
</tr>
<tr>
<td>Kel-F fluorocarbon</td>
<td></td>
<td>10⁻⁶</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>hard rubber</td>
<td></td>
<td>10⁻⁶</td>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td>paper</td>
<td></td>
<td>4</td>
<td>1.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

*A large number of the values quoted above taken from the Massachusetts Institute of Technology, "Tables of Dielectric Materials."*
Figure 1

The measurement of such large resistances is not easy, but by using thin samples and 500 volts or more applied to large electrodes, values up to about 10^10 ohm-meters can be measured accurately. The values quoted in Table I were measured at a relative humidity of 30% or lower. Moisture absorbed within or on the surfaces of high resistivity insulation can seriously lower the values measured.

Consider next the currents that flow through the block of insulation shown in Figure 1 when voltage V is suddenly applied by closing the switch. If V is a d.c. voltage, there is a rush of charging current which gradually decays to some steady value determined by the resistivity of the material and the applied voltage. However, when an a.c. voltage is applied, although most of the current leads the voltage by 90° (I_capacitive), a small but measurable current component is in phase with the voltage (I_resistive). The vector diagram of Figure 2 represents these two currents.

Now the a.c. current alone produces heat. The amount of heat is determined by the d.c. resistivity of the insulation in conjunction with some extra heat generated when the molecules of the insulation rub against each other as they move under the influence of the a.c. voltage.

The equivalent circuit of insulation could be represented circuit-wise by a resistance shunted across a "perfect" capacitor—that is, a capacitor to which all the current is out of phase with the applied voltage. For "good" insulations of the type we are considering, the ratio of the heat-producing current (I_resistive) to the capacitance-producing current (I_capacitive) is called the power factor of the insulation.

In other words, the power factor is the number by which the "apparent" power of a capacitor-resistor combination must be multiplied to obtain the actual watts of heat developed. The power factor is a number (usually expressed as a percentage) which can vary from 0% for a perfect insulator such as air to 100% for a perfect conductor.

For most commonly used insulators the power factor is less than 5%, and it may be as low as 0.02% for the best very insulators such as polyethylene or mica.

Now as indicated previously, the a.c. resistivity of an insulator is in part determined by the movement of the molecules under the influence of the a.c. voltage. The net result is to cause the power factor to change in a rather complicated manner with variations in the frequency of the measuring voltage. This is reflected in the power-factor columns in Table I which show it is meaning less to quote a power factor without specifying the frequency at which the measurement was made.

This variation with frequency illustrates why it is of utmost importance in many applications to choose a coil form of suitable material when working with R.F. circuits. For instance, a paper coil form would have a power factor of 1/2 at 60 cycles but 4% at 100 megacycles. And in comparing two different types of coil form material it is seen that the power factor of black Hastelloy is 1/2 at 100 megacycles while polyethylene is 1/8 at the same frequency. Thus the efficiency and Q of an R.F. circuit can very well be quite dependent upon the type of insulation used.

* The "apparent" power or "true apparent" shown by a circuit containing both resistance and reactance is Fig. 2 is obtained by multiplying the voltage across the circuit by the total current. Under these conditions, then, a pure reactance (inductive or capacitive) is shown in the meter only the "power." In the circuit shown in Figure 2, the power meter records the r.m.s. value of the total current (I) and hence the total "apparent" power of resistance and capacitance. Therefore, we define the power factor as the ratio of the actual power consumed by the circuit (current squared times resistance) to the apparent power shown by the meter (current squared times total resistance).

(Continued on page 6)
The "helping hand" operating this ivory-handled bug (hand-carved from walrus tusk) belongs to W9N2Z, winner of General Electric's 1933 Edison Radio Amateur Award. Though he never tops the monthly BPL list, he'll count words with anyone.

His 20-meter beam stays pointed north to squat CW to remote weather stations near the Pole where crews are lucky to get such more than twice a year. (Note Indiana state Oiler home plate.)

News of winning the Award came via 75-tone from 38 AF (SMARS) via W1CC (left) as W9N2Z was on his 4 pm-to-midnight trick as CBO 56 dispatcher.
AMATEUR AWARD WINNER

Stan starts each day with early trip to post office to pick up mail for arctic weather man. In 1953 he kept regular skeds with arctic stations 313 days.

XVI Louise serves lunch at the rig so he can keep two skeds with each station most days. She won a wrist watch from G.E. as a "Most Understanding Wife." Louise works the same hours as the OM as PHX operator for C&O.

Stan loves to explain his hobby to neighbors (left) and gets many souvenirs from devoted friends he has never seen (above). Traffic piled up when Award ceremonies broke up skeds—but he reports operations now on a current basis again.
It is a familiar fact that the capacity of a condenser depends on the area and separation of the plates, but perhaps not nearly so well appreciated is the fact that capacity also depends on the kind of medium between the plates. This has led to the use of the dielectric constants of the different materials which is customarily noted by the letter K. The capacity of the condenser of Figure 1 with a solid insulation between the plates and then with air between the plates. The capacitance obtained with air insulation divided by the capacitance obtained with solid insulation gives us the dielectric constant always 1. The K of the so-called "high-K" materials always may have a value of more than 1000 (see Table 1).

The principal effect of this number is to determine the capacitance per cubic inch that may be obtained in a capacitor. Thus a capacitor made with mica insulation could be made more compact than a paper-insulated capacitor of the same voltage (for the dielectric constant of paper is 2.5 and mica is 7). For the same reason, a Pyralin/diethyl capacitor is much smaller than an oil-filled capacitor of the same value.

The last of the more important electrical ratings assigned to insulation is the "puncture" or dielectric strength. This usually is expressed in volts per mil, and gives the measure of the amount of voltage necessary to puncture a piece of insulation. While the puncture strengths in Table 1 are quoted in volts per mil of insulation, these values are not applicable over a wide range of thicknesses. The puncture strengths in Table 1 apply to measurements made with flat electrodes carefully polished and rounded edges on insulation about 1/16 inch thick. This condition partly is attained in practice with the result the strengths listed in Table 1 are all apt to be higher than would be encountered in practical situations. Thus safety factors of the order of 100% must be applied to any design based on these numbers.

Although the listing of puncture strengths is the most exciting aspect of the dielectric rating of an insulating material, it should be noted (a) Glass (3000 psi) at ordinary pressures have puncture strengths of the order of magnitude of 10,000 volts/mil, even when considered in the case of mica and very thin plastic sheets (a few mils) which may have a puncture strength as large as 1000 volts/mil.

A fact worth noting is that breakdown usually culminates in a high-temperature arc. While this is of little consequence with air and ceramic materials, organic insulation will be charred by the arc and the carbon track created will then break down at a much lower voltage than that which caused the initial failure. This fact may be of importance when attempting to design for high voltage applications where arcing is expected. Often breakdown occurs in transformers where voltage taps are brought out from the windings. If the charred insulation is not removed carefully with a knife or razor blade, and the resulting void filled with paper or mica instead of glass, then performance may sometimes be saved.

Breakdown between two conductors in certain situations may be eliminated by inserting a sheet of solid insulation between them, a piece of mica or thin sheet of plastic often will do the trick.

Further, moisture absorbed on the surface of plastics will cause their power factor (and attenuation per foot) to rise. Almost every bath that has operated in wet weather with two conductors insulated with polystyrene has noticed this effect. By actual measurement at 100 megacycles, the attenuation per hundred feet of one variety of twin lead conductors increased from 1.3 decibels to 6.5 decibels when its surface was wet. The application of water-repellent materials like silicones to these surfaces often will improve performance of insulation under adverse moisture conditions. All the values quoted in Table 1 apply to measurements made at room temperature. Differently, moisture, at higher temperatures the performance of insulating materials becomes poorer. As the operating temperatures of a given insulation is raised, the resistivity, dielectric constant, and puncture voltage decreases lower while its power factor rises—WIRE.
Judging from the requests we've had for back copies of G-E HAM NEWS concerned with SSB, the rush to this type of emission definitively is on. SSB line work is so fast that there are an awful lot of long silences in these QSOs. Even the most long- winded fans might find they can run out of steam pretty fast on SSB.

One result of this situation has been the building up of super round tables—round tables of a size that would be completely impractical in push-to-talk operation. But in SSB talk-to-talk operation anyone can stick in his two cents just by speaking up.

Did we say "anyone"? Well, you're right. All the lighter-power boys in the round tables really speak up. But the unfortunately lower-power boys (6 watts peak or 3 watts average) are never in the round tables because everyone has his receiver tuned down to the roof and has tuned out when the 30 MHz peak goes up. So even though the 600+ boys can work all districts without straining their diameters, they get lost in the round tables. Thus the rush is on not only to SSB, but to high-power SSB.

One thing is lacking in the SSB world as we write—the honest-to-goodness traffic nets. SSB offers perhaps more to the traffic man than to other operators. So far, SSB has been the pride and joy of, first, the more technical-minded hams and now the rag-chasers. But as equipment and circuits become more standardized and we find ways to lock the stability problem, we feel SSB has a future in traffic work.

Don't think for a moment we mean that the tech- nicians and rag-chasers are going to turn into traffic men en masse. Not at all. The biggest single factor in traffic nets are the operators—the guys and gals with a particular kind of intense persistence and whose main objective in life is to "get that message through." They're born, not made. And we feel sure that when they have access to SSB communications, they'll be no stopping them. Of course, a complete changeover on an entire traffic net is a problem not wholly technical— a problem of economics. (How many hams can afford to strap an AM or FM rig they've given, in effect, their life's blood and money away?)

The transition will be slow. But we feel that the SSB traffic world is developing on its own plane.

Don't think that with all this talk of font work we're slighting old, reliable CW. We ask around among our friends every once in a while about whether they prefer font or CW, and 9 out of 10 say font and half as far as we can figure. Lots of fellows like to work both. Our editor himself used to have one of the best CW rigs in the west and surely a work CW bug, too. One of the best 80-meter CW rigs we know of is the "Baldwin" described in G-E HAM NEWS, Volume 3, No. 5. It's a two-control, two-stage VFO job that's a delight to operate. It uses a 1614 (but a 6L5 works fine) and a GL-42DI/4-125E. Be glad to send you one of these back copies.

In Cardiff, Wales, a case of TVI was traced to the 43-24 inch pentium of a spring generator clock, and was remedied by grounding the metal works, according to "Sparks," the Braddon, Manxsha, club bulletin . . . the Al-Ber-Ben Club of Ottawa, reports "Ham Radio," has started an annual award (a first-class commu¬ nications receiver) for the member who will be adjudged as having done the most for amateur radio during the year. The award will be presented at the upcoming convention. In the Northeast Nebraska area where only 2 amateurs are known to own a car and a year ago . . . Oldtimer's hearing tapers off at 10,000 psi or so while the younger lad easily catches 15,000 psi, according to W9GFA in a talk on local problems at a meeting of Tri-State ARA at Evansville, Ind.

Hams have been known for the fine job they do in policing their own ranks. Recent comments from QO's, for example, indicate that their friendly warnings to brother hams are received in good grace and with fervent thanks in nearly every case.

Now we note comments in two widely separated local ham club bulletins which indicate some organized self-policing may be in order in a new field—among those fortunate enough to be granted auto license plates bearing their call letters.

The license plate program has met with considerable success throughout the nation—and has given us a great house in public. In many cases we are thus put on a level with doctors and other public servants.

However, as we obtain this stratum we shall have to remember that it behoves us to live up to our new standing by adding decor and courtesy on the road. Need not be said to them that every traffic report is a "message," but every little bit helps make a black eye for ham radio. And suppose through our carelessness it should be written in some "bucket"? Suppose it's a broken, twisted body of a child on the highway? We see such pictures in the newspapa once in a while. I fervently hope I never see one which includes a "murder case" bearing ham call-letter license plates.

In this thoughtless pain and unpleasant subject. Sure is. But not half as painful and unpleasant as the one on page 1. No, I am not saying that I think thoughtless, now, beforehand, may prevent the real thing from ever happening.
A STREAMLINED RECTIFIER

The new "Service-Designed" GL-5U4-GA has slightly higher output voltage and current ratings than the old 5U4-G and a streamlined envelope and studler construction—all of which make it more adaptable to ham use.

Here's the difference:

OLD 5U4-G

NIP

NEW

GL-5U4-GA

MAXIMUM RATINGS

Steady state peak current per plate... 450 mA

Peak plate current per plate... 150 volts

Maximum plate voltage... 250 volts

Typical Op.:

With choke-feed input:

AC input supply voltage per plate... 120 volts

DC input current... 50 mA

DC input voltage... 250 volts

With direct-fed input:

AC input supply voltage per plate... 120 volts

DC input current... 50 mA

DC input voltage... 250 volts

The envelope is shorter and narrower than the old model, and thus serves spacers. The nose supports at bottom as well as top—which together with the new "beacon" construction makes a sturdy tube.

Shock and vibration tests show the new 5U4-GA can withstand the hard usage of Field Day and portable operation.

OLD 5U4-G  GL-5U4-GA