EMI gasket design theory and practice is a specific application of the principles and procedures that apply to the design of any gasketed joint. Therefore, a very generalized gasket design theory is presented first as the basis for the specific EMI gasket design procedures. The EMI gasket design theory and procedures follow and are presented as a specific application of general gasket design.

GASKET DESIGN—WHAT GASKETS DO

All gaskets whether they seal EMI, high pressure fluid, make a container dunk proof or simply keep forced ventilating air from escaping at a door-to-cabinet joint, do so by conforming to the unavoidable irregularities of the mating surfaces of a joint. Some examples are:

—The joint between a garden hose and water faucet.
—Housing for an emergency radio to be dropped into the sea.
—Joint between the cover and enclosure for a radar pulse modulator.

In each example the joint has two relatively rigid mating surfaces, and neither surface will be perfectly flat. When they are mated without a gasket, even very high closing forces will not cause the two surfaces to comply completely with each other, and the resultant gaps will allow leaks. A gasket resilient enough to comply to both surfaces under reasonable force will eliminate these leaks. The garden hose example makes this point very well; just try to prevent a leak by force alone without a gasket, but with a gasket in the hose fitting compressing against the faucet, even hand torque results in a watertight joint. To try to get the same watertightness by accurate machining of both surfaces would be prohibitively expensive. In most cases, the least expensive way to obtain a tight joint (watertight, oil-tight, or EMI tight) is to make the mating surfaces to normal tolerances on flatness, rigidity, and tolerance build-up and add a gasket to compensate for the resulting misfits between the two surfaces.

GASKET DESIGN THEORY

The degree of misfit needs to be defines so that design procedures can be clearly outlined. This misfit is commonly called "joint unevenness" and is designated as H and is defined in Figure 1. It is the maximum separation between the two surfaces when they are just touching. If the surfaces are not rigid, then the joint unevenness would also include any additional separation between the two surfaces due to the distortion of the joint when pressure is applied.

Figure 2 shows the same joint with a gasket installed. The dashed lines indicate the height of the gasket, H_g, before it was compressed. The minimum compressed gasket height, H_{min}, occurs at the point where the surfaces would touch without a gasket. Maximum compressed gasket height, H_{max}, is at the point of maximum joint unevenness. Note that the joint unevenness of the mating surfaces is equal to $H_{max} - H_{min}$. This concept must be kept in mind in all gasket design.

REQUIRED COMPRESSION PRESSURE

Three factors determine the required compression pressure on a gasket; its resiliency, the minimum pressure required for a seal, and the total joint unevenness.

Resiliency—This is the amount a gasket compresses per unit applied compression pressure. Resiliency is usually expressed in (% of original gasket height)/psi. A soft gasket would compress more than a hard gasket with the same applied pressure. Or stated the other way, a soft gasket would require less pressure than a hard gasket to compress the same % of gasket height. For instance a sponge neoprene gasket might compress 10% under an applied compression pressure of only 6 psi, but a solid neoprene gasket would require 50 psi for the same 10% deflection.

Minimum Pressure for Seal—As already stated, a gasket must at least make contact at the point of maximum separation between the mating surfaces (H_{max} H_g). Actually in most cases the pressure at this point must be a stated minimum in order to assure a seal. This would be rather easy to understand in the case of a high pressure hydraulic system. If there is not at least some required minimum pressure at the point of H_{max} the oil would blow by between the flange and the gasketing material. The pressure at H_{max} point must be high enough to prevent blow-by. For EMI gaskets this minimum pressure is determined by the pressure required to break through corrosion films and to make a suitable low resistance contact. For most EMI gaskets this is 20 psi, but can be as little as 5 psi.

Average Pressure—The average pressure applied to the gasket must also be large enough to compress the gasket so that the minimum gasket height subtracted from the maximum gasket height (which was determined by the minimum pressure required from the previous paragraph) is equal to the joint unevenness, that is $H_{max} - H_{min} = \Delta H$.
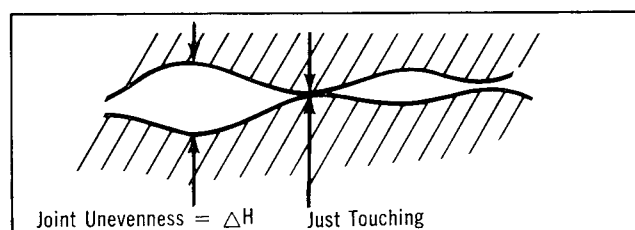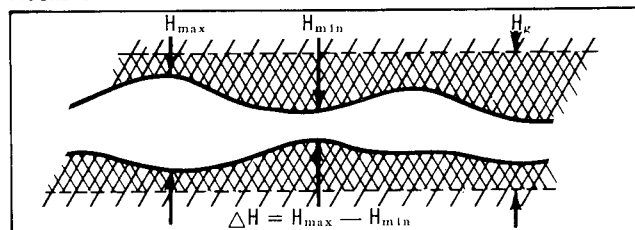
FIGURE 1

Joint Unevenness = ΔH Just Touching

FIGURE 2
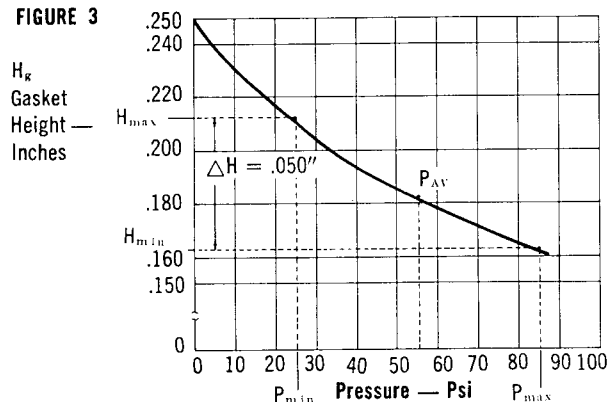

$$\Delta H = H_{max} - H_{min}$$

GASKET HEIGHT

To obtain the required seal from a gasketed joint, the gasket height must meet these criteria:

1. The pressure at point of maximum separation must be at least the minimum pressure to obtain the required seal.
2. The difference between maximum and minimum gasket compressed heights must be equal to the joint unevenness of the mating surrfaces ($\Delta H = H_{max} - H_{min}$).
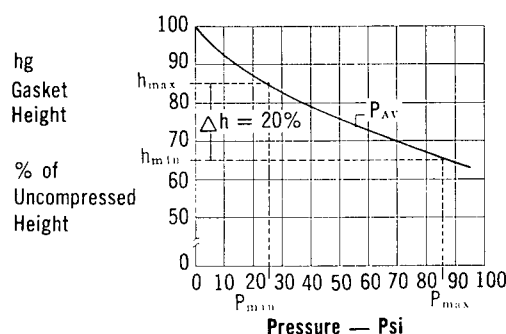
FIGURE 3

H_g Gasket Height — Inches

These principles are illustrated by reference to Figures 2 and 3. Figure 3 is the compression characteristic for the gasket material used in the joint illustrated in Figure 2. In this example the minimum pressure for a reliable seal is 20 psi. As shown, minimum pressure is actually 25 psi; the minimum pressure requirement has been met. Gasket height at this point is .212". Joint unevenness is .050" so the minimum gasket height is .212–.050 = .162. The second requirement has been met. From the curve, the pressure at this point is 85 psi. Average pressure is estimated by $\dfrac{P_{min} + P_{max}}{2}$, in this case $\dfrac{25 + 85}{2} = 55$ psi.

Average pressure is important in estimating total force required to compress the gasket.

Gasket compression characteristics are most frequently given in terms of percent of gasket height so that one curve can be used for many actual gasket heights. Figure 4 is a plot of the characteristics shown in Figure 3 except heights are given in percent of gasket height. To distinguish actual heights from heights expressed in percent of gasket height, the latter are designated by lower case h.

FIGURE 4

hg Gasket Height

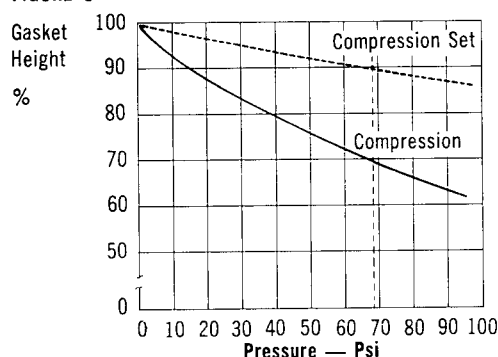% of Uncompressed Height

COMPRESSION SET

Some gasket materials take a compression set; that is, they do not return to original gasket height after compression. This is illustrated in Figure 5. The compressed height is indicated by the solid line. When compression pressure is removed, the gasket returns to the height indicated by the broken line. This is compression set. The importance of compression set depends on how the gasket is used.

CLASS A, PERMANENTLY CLOSED–If the gasket is used under a component that will, in all probability never be removed, the compression set is unimportant. It would show up only on disassembly. This type of joint is called "permanently closed" and identified as Class A.

CLASS B, REPEATED IDENTICAL OPEN-CLOSE CYCLES–Many gaskets are used in joints that are frequently opened and closed but always in the same manner (hinged door or symmetrical cover, etc.). In this case minimum compressed gasket height will always occur at the same place. This will also be the point of maximum compression set. In effect, original gasket height has been reduced at this point, but the gasket is still being compressed. For instance, Figure 5 shows compression and compression set characteristics for a gasket material (set is more severe than normal for emphasis).

FIGURE 5

Gasket Height %

CLASS C, COMPLETELY INTERCHANGEABLE–The problem of compression set is much more severe when there is complete freedom of positioning on repeat closures. A specific example would be a round gasket in a waveguide that might be removed and reused in almost any position relative to points of minimum and maximum compression. The compression set height at point of maximum compression may actually be less than minimum compressed height! It would therefore be possible to not make contact at all between gasket and mating surfaces at this point.

EMI GASKET DESIGN PROCEDURE

EMI gasket design involves making suitable matches and trade-offs between the available EMI gasket materials and their characteristics on the one hand, and the performance requirements of the equipment and the design constraints of the mating surfaces on the other.

GASKET CHARACTERISTICS–Thickness, size, shape, compressibility, corrosion resistance, EMI rating, pressure sealing capability, compatibility with mating materials, temperature range, etc.

APPLICATION REQUIREMENTS–(usually equipment performance specifications). Amount of shielding, amount of pressure sealing, environmental exposure (temperature, salt spray, ambient pressure, corrosive material, etc.).

APPLICATION CONSTRAINTS–(usually imposed by equipment housing design). Space available, compression force, joint unevenness, contact surface characteristics, attachment possibilities, etc.

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USING STANDARD GASKETS

The designer should know or estimate:
1. Joint unevenness.
2. Available compression.
3. Shielding required.

The object of EMI gasket design procedure is to fit the application requirements (joint unevenness, available compression forces, and shielding requirement) to the gasket characteristics (compressibility and EMI shielding capability).

    a. *Low frequency magnetic field penetration*—Here the important factors are overall conductivity, permeability (only if in a permeable shield) and width. Overall conductivity is affected by gasket conductivity, mating surface conductivity and applied pressure. Wherever possible a gasket material with superior conductivity should be used.

    b. *High Frequency Leakage*—The other EMI problem area is leakage above 100 MHz. Here conductivity is less important but compressibility more important; the gasket must make contact continuously to both surfaces to assure that there will be no gaps through which high frequency (short wave-length) EM energy can leak.

Average Shielding Problems—In general the same reasoning outlined for maximum shielding will apply; choice of gasket material and contact surface is most important, pressure is secondary. If low frequency magnetic shielding is not a severe problem, then a minimum pressure of 5 to 20 psi may well be adequate. This reduction of minimum pressure can be very important because it increases the Δh (gasket compression range) significantly for the same average applied compression pressure.

Minimum Shielding Problems—Especially when little or no low frequency magnetic shielding is required the minimum pressure could be as little as 1 to 5 psi.

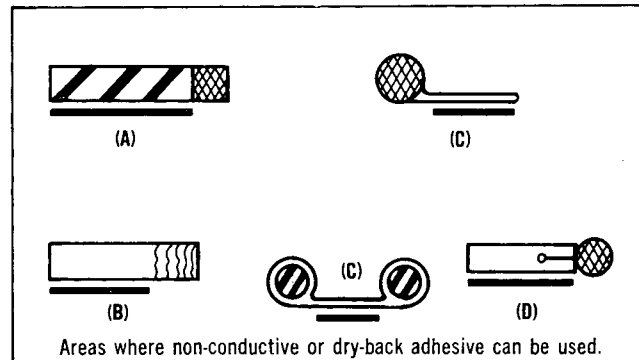The important matches and trade-offs are:

—Gasket height and compressibility must be large enough to compensate for joint unevenness under the force available.

—The gasket must be capable of providing the required EMI sealing and pressure sealing when compressed by available force.

—There must be sufficient space for the gasket within the design limitations of the application.

—The gasket must be attached or positioned by a means that fits in with the joint design.

—The metal portion of the EMI gasket must be sufficiently corrosion resistant and compatible with the mating surface.

—The EMI gasket must meet the temperature needs of the equipment specifications.

Pressure Sensitive Adhesive—This is often the least expensive method for attaching EMI gasket materials; installation costs are often drastically reduced with only a slight increase in cost over a material without adhesive backing. As a matter of fact, most sales of sponge elastomer materials are for applications that do not require any pressure sealing; the adhesive backed rubber portion serves only as an inexpensive attachment method for the EMI portion!

In all cases the designer specifying non-conductive adhesive attachment must include adequate warnings in the applicable drawings and standard procedures for production personnel that the adhesive is to be applied **only** to the portion of the gasket material not involved with the EMI gasketing function. Experience teaches that installation workers will, either through carelessness or a misguided desire to do a better job ("This gasket would hold better if I glued all of it rather than half of it"), apply the non-conductive adhesive to the EMI gasket portion also. This will seriously degrade the EMI performance.

Bond Non-EMI Portion of Gasket—Since many very good non-conductive adhesives are now available, bonding a gasket product in position by applying the adhesive to the portion that is not the EMI gasket (which can be insulated from the mating surfaces by a non-conductive material) is often a very good way of mounting EMI gaskets.

FIGURE 6

Areas where non-conductive or dry-back adhesive can be used.

All aluminum EMI gasket products should be avoided since they make poor electrical contact. They should be used only when equipment specification explicitly require that only aluminum EMI gaskets be used against aluminum shields. Secondly, mating contact surfaces should be treated for best conductivity (tin coated, cadmium plated, conductive treatments of aluminum). Non-conductive protective coating such as paints and anodizing of aluminum are prohibited in all EMI gasket contact areas.

(The above material has been furnished courtesy of the Metex Corporation).

SEE THE

EMI GASKET DESIGN CHART

IN BACK OF BOOK

FINGER STOCK

Another form of EMI/RFI gasket used in many applications is contact fingers, often referred to as finger stock. They are available in various configurations including straight strips, corner strips and circular rings with inside or outside contact tips.

APPLICATIONS:

The fingers are most often used as a RF gasket where frequent access through the opening is required. They can be found around the periphery of most shielded room doors in parallel rows—two and three deep. Here, their wiping action as it is compressed, is a most desirable feature since it cuts through film and dirt which can build up along the mating surfaces. Figure 7 illustrates the wiping action of finger stock.

The fingers can also be used behind panels and drawers where it not only provides RF shielding, but also assures a good ground contact across the mating surfaces. Circular finger rings can be used to ground metal shafts where they penetrate a panel and protect against RF leakage. Their wiping action allows the shaft to rotate without appreciable drag.
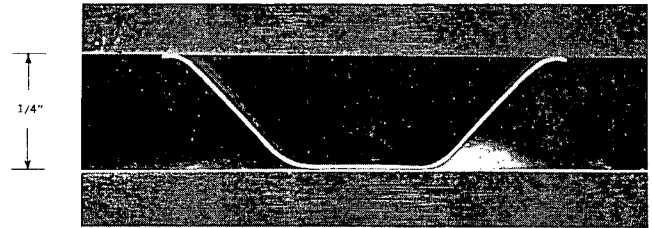
CHARACTERISTICS:

Finger stock is made of high-performance beryllium copper which has a relative electrical conductivity of 22 to 28. It can be purchased in many standard finishes including gold flashed, gold plated, silver plated, bright finish or as heat-treated ready for the user to apply the finish. The ring fingers are also available with localized deposits of silver or gold on the contact tips.

The finger strips feature a mechanically balanced design to provide high dynamic range, long endurance life and multiple lines of contact under relatively light pressure. Attenuation against electric fields of more than 100dB at 200kHz, 400kHz, 400MHz and 10GHz has been measured for a single rectangular enclosure.
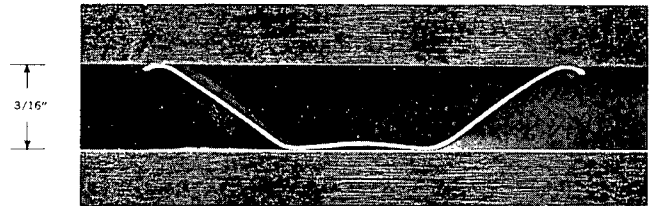
Finger stock can be fastened in place with rivets, clips, and epoxy or can be soldered. The newest technique is finger strips with a self-adhesive backing. Referred to as "Sticky Fingers" by Instrument Specialties, the pressure-sensitive adhesive was developed to provide an extremely tight permanent bond. The adhesive strengthens as it cures with age. Sticky fingers are unaffected in temperature ranges from -65°F. to 160°F. The adhesive also meets most salt spray, shock and humidity cycle tests.

To provide for an increase in the shielding effectiveness against magnetic fields, the sticky fingers can be furnished with a magnetic core insert. As an example, tests have shown that magnetic field shielding effectiveness has been increased from 14 to 18dB at 400Hz and from 46 to 59dB at 14kHz using the magnetic insert.

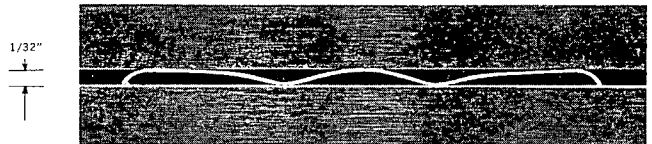**end views of linear gasket 97-436 compressed between flat surfaces**

1/4"

Three lines of contact occur when gap is 1/4". (Note: This photo was made after the gasket had been compressed to 1/64", and released.)

3/16"

At 3/16" gap there are four lines of contact due to arching of center.

1/16"

Note increased arching of center at 1/16" gap. This produces wiping contact with the mounting surface.

1/32"

At 1/32" gap the tips of the fingers are in contact with the mounting surface, and the center arch is in contact with the closing surface, making a total of seven lines of contact.

1/64"

At least nine lines of contact occur when the gasket is compressed to 1/64". (Note: Recovery from this deflection is excellent. See top illustration.)