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AD#: TITLE:

BROADBAND THERMOPLASTIC RADOMES

AD-P004 369

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Radomes requiring frequency coverage from S through K band present a difficult design challenge. Past experience with broadband antenna systems has shown that a low finess ratio "A" sandwich radome offers the best electrical performance. However, a blunt "A" sandwich which performs well electrically typically has skins which are too thin to provide adequate rain erosion and ground handling protection. Therefore, the designer has been forced to either sacrifice electrical performance or face increased rain erosion and ground handling damage. To achieve the necessary electrical and mechanical properties, new radome designs incorporating thermoplastic materials have been developed. These new thermoplastic radomes can meet both the mechanical and electrical requirements while remaining relatively low cost.

The standard materials used for an "A" sandwich radome include fiberglass composite skins seperated by a nomex honeycomb core. To achieve adequate rain erosion protection from a fiberglass composite material the outer skin needs to be 0.040" thick or greater.[1] However, to perform well electrically, the outer skin thickness should be 0.020" or less. In an effort to circumvent this problem, Ed Greene from IBM developed a 100% polycarbonate radome. By changing from traditional composite materials to polycarbonate materials both electrical and rain erosion performance were improved. Texas Instruments has taken the work done by Ed Greene and expanded it, and is currently producing these polycarbonate radomes under contract to the military.

The 100% polycarbonate radome consists of two vacuum molded polycarbonate skins bonded to a polycarbonate honeycomb core.[2] An injection molded glass filled polycarbonate base ring is bonded into the structure for rigidity and attachment purposes. The entire radome is bonded together using an elastomeric polyurethane adhesive.[3] A cross-section of this structure is shown in Figure 1.

The electrical performance of polycarbonate radomes is superior to their fiberglass composite counterparts. Most of the reason for the improved performance is the relatively low dielectric constant of the polycarbonate (2.77) compared to fiberglass (4.3). A second order effect is the lower loss tangent of polycarbonate (0.007) compared to fiberglass (0.02). Because the dielectric constant of polycarbonate is less than fiberglass, the skin thickness can be physically increased while remaining electrically constant. Figures 2 and 3 show a three dimensional contour plot of two "A" sandwich wall designs. Figure 2 shows a polycarbonate wall with 0.025" skins and a 0.190" core. Comparing this to Figure 3, which shows the same physical design with fiberglass skins it is observed that the polycarbonate radome offers increased performance. It should be noted that the dielectric constant of the polycarbonate honeycomb is very nearly that of nomex (1.08). However, because of fabrication methods used in producing the polycarbonate honeycomb, it is isotropic with respect to orientation while the nomex honeycomb is not. The orientation effect found in nomex honeycomb is not great but is measureable as is shown in Figure 4.

The very high impact strength of polycarbonate translates into excellent rain erosion resistance and this is the primary reason for it's choice for thermoplastic radomes. The high impact strength also makes the radome resistant to handling damage. A thin skinned polycarbonate sandwich radome can be dropped from a height of five feet without being damaged. In comparison, a fiberglass laminate would suffer extensive damage. Even a drop of one foot will produce fracture lines in the laminate. These lines serve as porous paths for water migration into the honeycomb.

The reason for the increased resiliency of the polycarbonate radome over the fiberglass radome is threefold. First, the brittle nature of the fiberglass skins does not allow significant deformation. Therefore when struck, the fiberglass material cannot absorb the impact energy and the skin cracks. On the other hand, the polycarbonate skin deforms elastically on impact. This allows the polycarbonate skin to absorb the impact energy and then spring back to its original shape. Second, the standard nomex honeycomb core becomes crushed with repeated impacts. After the core crushes, the skin becomes unsupported and skin failure occurs. The polycarbonate core does not crush as quickly with repeated impacts. Instead, it absorbs tne impact energy through elastic deformation then springs back to its original shape. Thirdly, the bonding agent between the skins and core affects resiliency. For the standard "A" sandwich radome, the resin in the skin acts as the bonding agent. Usually this resin is a brittle type of epoxy or polyester. On impact, this bond cracks in the same way as the fiberglass skin. For the polycarbonate radome, the bonding agent is an elastomeric urethane. Upon impact, this adhesive deforms elastically to flex with the skins and the core. The structural integrity of the bond is not degraded even after many impacts. Figure 5 shows the rain damage mechanisms of the standard "A" sandwich wall compared to the polycarbonate "A" sandwich wall.

The excellent impact properties of polycarbonate are accompanied with low stiffness in comparison to a fiberglass laminate. The modulus of elasticity is about one tenth, and the strength is about one eighth of a fiberglass laminate. Because of the reduced strength of polycarbonate, special design of the base is required. For spheroidal radomes, the nose will usually have adequate strength when fabricated from polycarbonate due to the special stiffness properties of spherical surfaces. Toward the base, where the radome is usually more cylindrical or gently curved, extra mechanical stiffness will be needed. In regions outside of the window area, the injection molded base ring is integrated into the wall. Additionally, the glass filled base ring acts as a stabilizer to prevent cold flow of the polycarbonate skins around the attachment screws. Figure 1 illustrates the construction of the reinforced radome.

While polycarbonate radomes offer distinct electrical, rain erosion and ground handling advantages over traditional fiberglass radomes, there are some drawbacks. One of the major inadequacies of polycarbonate is its low operational temperature. Typically, polycarbonate radomes cannot be used where temperatures reach above 230 degrees F. Not only does the polycarbonate become weakened, but the urethane adhesive degrades. This precludes using a polycarbonate radome for sustained speeds of Mach 1 or above. Another disadvantage of polycarbonate is that it is not resistant to some chemicals. This lack of chemical resistance might cause problems where the radome is subjected to flightline environments. To eliminate these two drawbacks of polycarbonate radomes, while still retaining the desirable electrical and rain erosion properties, new materials need to be used.

Texas Instruments is investigating the use of new thermoplastic materials for radome applications. These new second generation materials were chosen for their high temperature capability and their relatively high impact resistance. Additionally, each of these materials offers a substantial increase in chemical resistance over polycarbonate. Candidate skin materials include polyarylsulfone, polyarylate, and polyether-ether-ketone. Each of these materials is capable of withstanding temperatures of 320 degrees F and above. Samples of these materials have been sent to Dayton, Ohio for rain erosion testing. After the samples have been tested and a single material is selected, the process of how to form the skins into the desired shape will need to be determined.

A good candidate for a high temperature core material is Ultem 1000.[4] This material is a polyetherimide thermoplastic which retains adequate strength up to 325 degrees F. The impact resistance of this core closely approximates that of a polycarbonate core which makes it a logical choice. To further insure that the core does not crush while impacting rain at supersonic speeds, a 1/16 inch cell size will be used. This cell size gives a core with density of about 9 pounds per cubic foot and should be of more than adequate stiffness to insure that failure does not occur. Testing using a 1/16 inch cell polycarbonate honeycomb has indicated that the rain erosion properties of this higher density core are more than adequate. Because this core has a high stiffness value, it will need to be preformed to the desired shape before the radome can be assembled together. Preliminary tests on the high density polycarbonate core, show that preforming the core will not be a serious problem.

With a good choice of skin and core materials the final area of investigation involves an adhesive. Several different high temperature elastomeric adhesives are now under investigation. Some of these adhesives include silicones, urethanes, fluorosilicones, flourohydrocarbon (Viton),[5] and epoxies. Preliminary work indicates that silicones form too weak a bond to function adequately. Urethanes do not retain adequate strength at elevated temperatures to be of much use. Fluorosilicones hold promise but is has been difficult to locate vendors. Fluorohydrocarbon (Viton)[5] has been used as a rain erosion coating and appeared to be a likely candidate. However, the ratio of 20% adhesive to 80% solvent (Methyl-Ethyl-Ketone) attacked some of the thermoplastics. More work in this area is needed including trying another, less active, solvent base. Current work indicates that the high temperature epoxies hold the most promise of working. The only drawback to an epoxy is that it is very brittle and degrades quickly on impact. More work is being conducted in the epoxy area including adding a softening agent to allow the epoxy to remain elastomeric while retaining it's high temperature properties.

Then need to broadband high velocity radomes is driving the thermoplastic radome technology into higher temperature ranges. The current broadband polycarbonate radomes cannot fulfill the requirements at these elevated temperatures. Therefore, Texas Instruments is continuing to investigate the use of higher temperature thermoplastics, elastomeric adhesives, and the associated fabrication processes necessary to fabricate these second generation thermoplastic radomes.

FOOTNOTES

1 Schmitt, G.F., Jr., "The Subsonic Rain Erosion Response of Composite and Honeycomb Structures", SAMPE Journal, Sept/Oct 1979.

2 Plascore Inc., Zeeland, Michigan; Manufactures Polycarbonate Honeycomb.

3 Hartel Enterprises Inc., Pacoima, California; Produces HE 17017 Urethane Adhesive.

4 Ultem is a tradename of General Electric.

5 Viton is a tradename of DuPont.

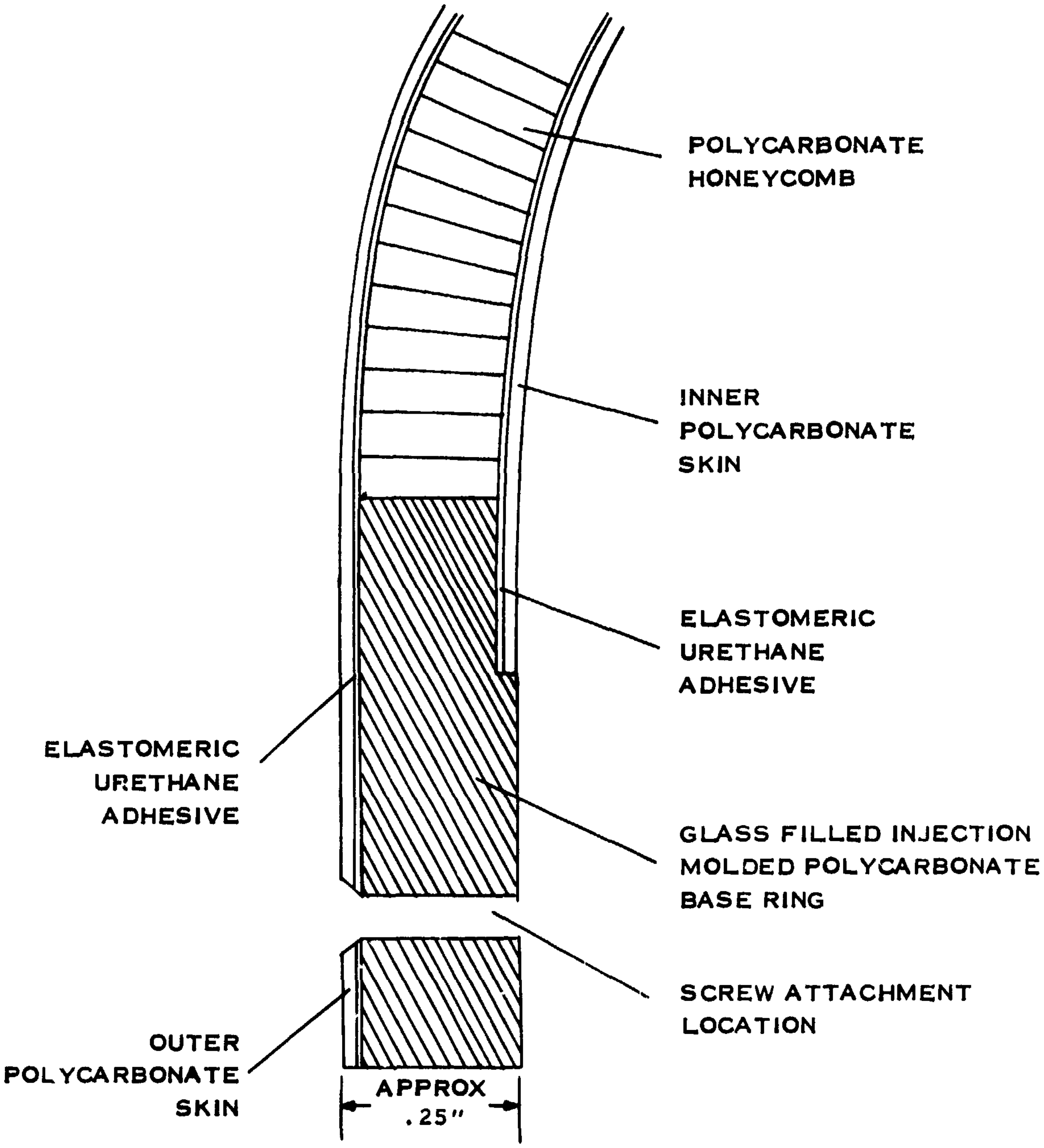


FIGURE 1. CROSSECTION OF POLYCARBONATE RADOME WALL AND BASE RING

WORST CASE ONE WAY POWER TRANSMISSION

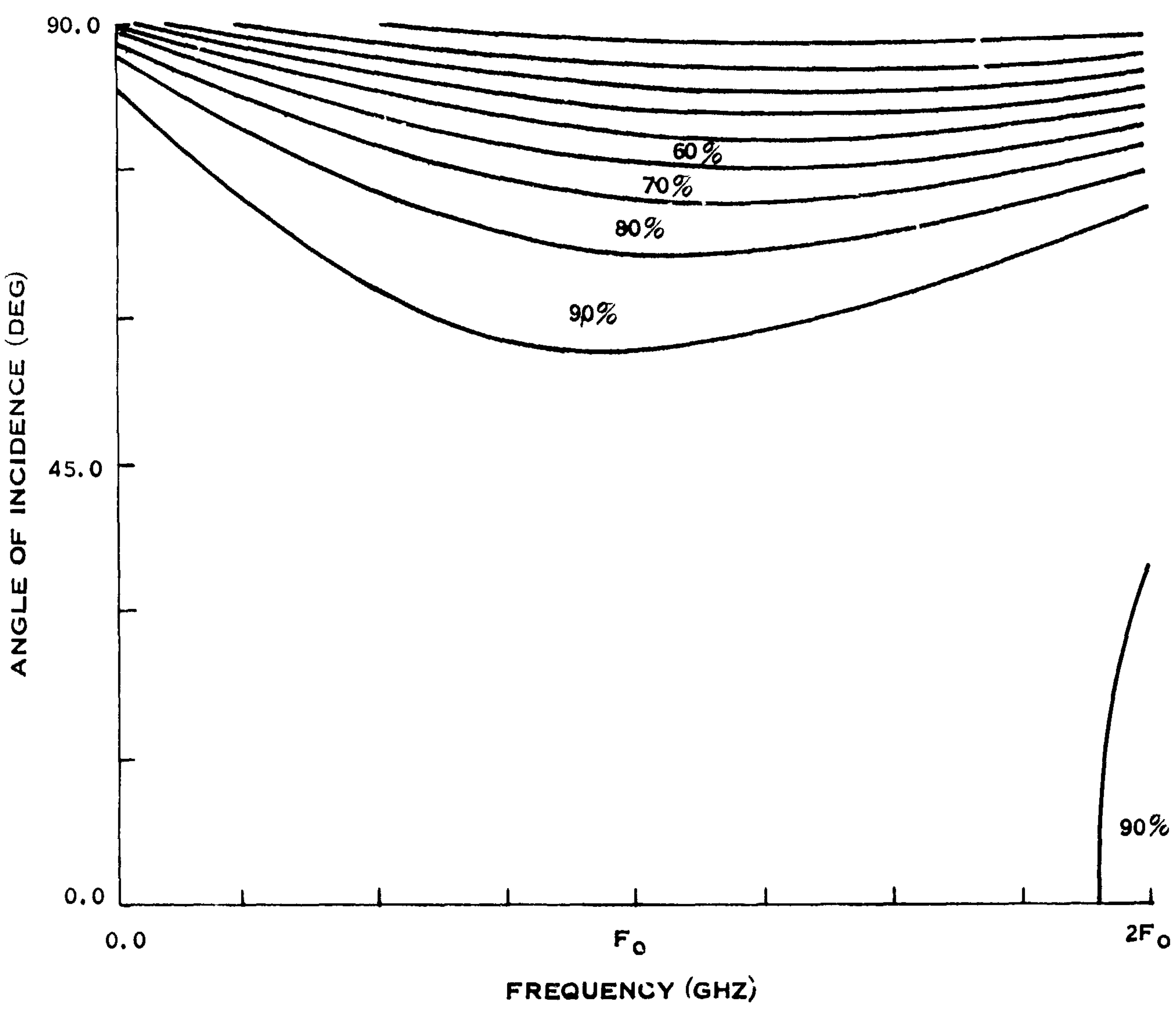


FIGURE 2. POLYCARBONATE RADOME WITH
0.025 INCH THICK SKINS,
0.190 INCH THICK CORE

WORST CASE ONE WAY POWER TRANSMISSION

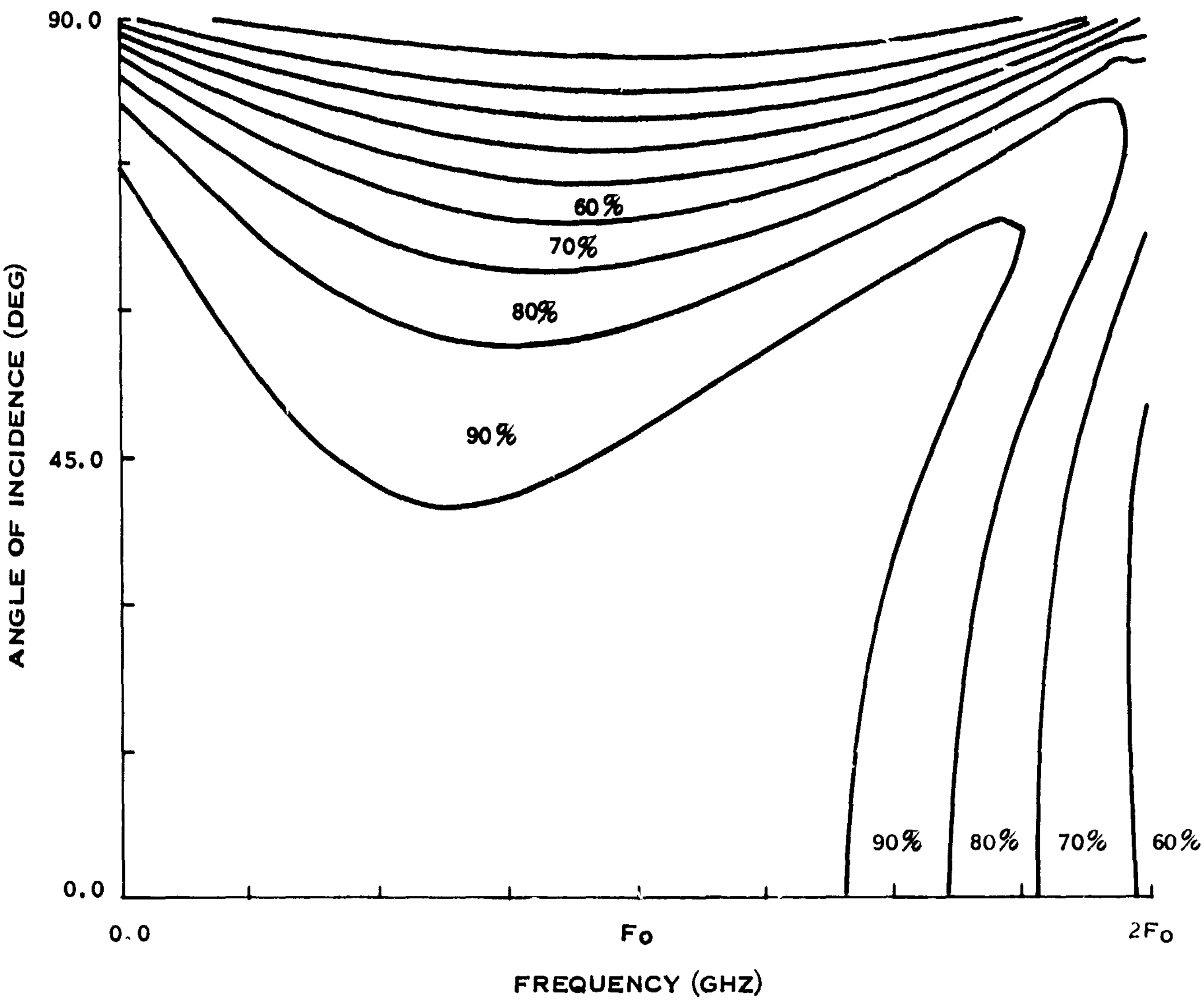
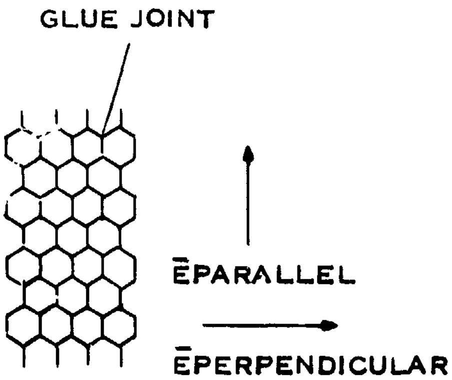


FIGURE 3. FIBERGLASS RADOME WITH
0.025 INCH THICK SKINS,
0.190 INCH THICK CORE



DIELECTRIC CONSTANT MEASURED AT X BAND*	
$\bar{E}$PARALLEL	$\bar{E}$PERPENDICULAR
1.09	1.07

* HEXCEL NOMEX HONEYCOMB 3.5 LB/FT^3, 1/8" CELL SIZE

FIGURE 4. NON ISOTROPIC EFFECT OF NOMEX HONEYCOMB

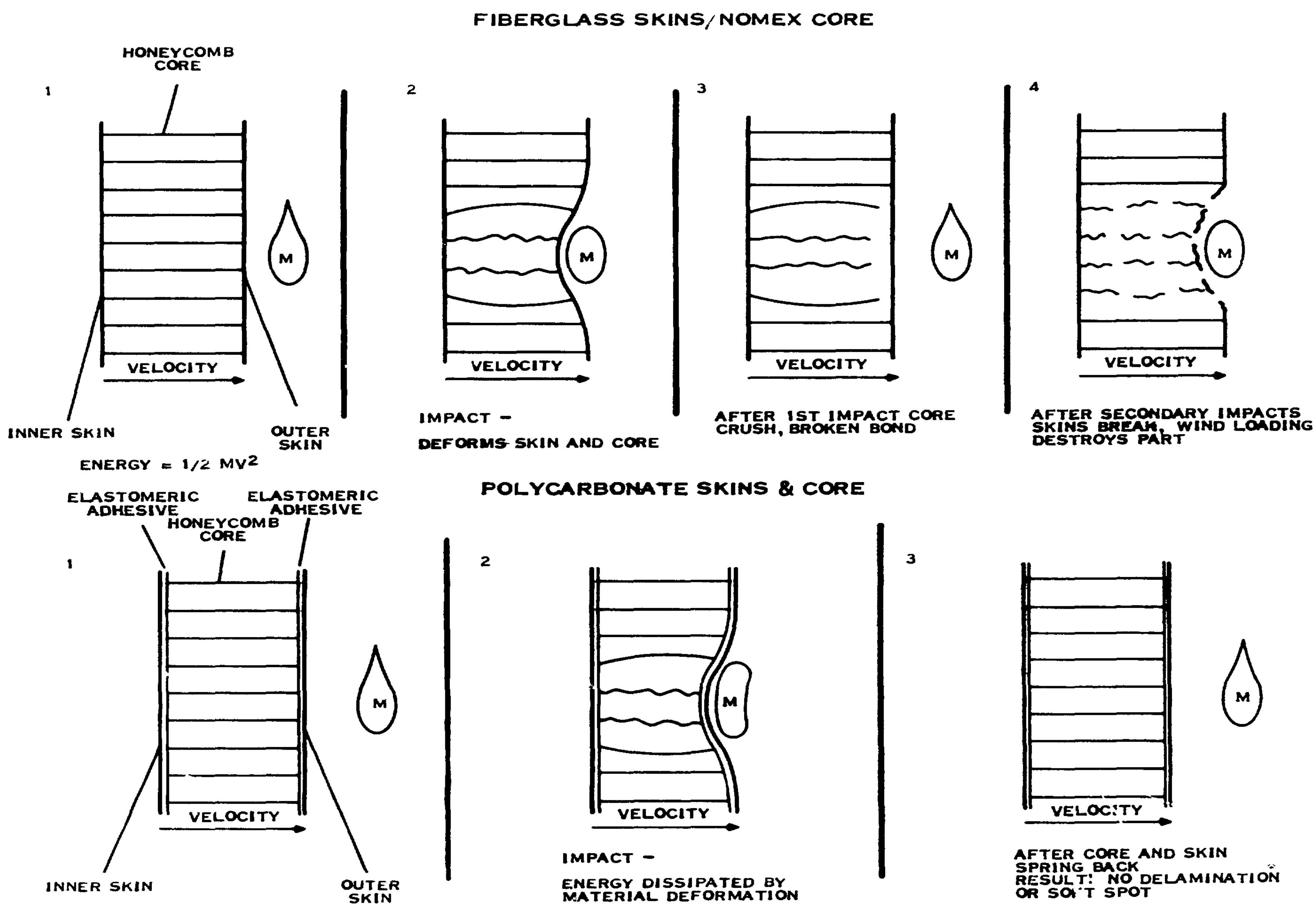


FIGURE 5. RAIN DAMAGE MECHANISM FOR THIN SKIN "A" SANDWICH