The Joy Of Rubber & Plastics

PREFACE

This book was written for all of us who grew up in a time when closed cell sponge rubber was a taboo subject. One which we dare not ask either our parents or grandparents to explain, let alone a sales manager. If you are like most people from our generation, you had to learn about closed cell sponge on the streets or in dark alleys. Even after we progressed into our respective business careers little, if any, information was available as to the basic facts of how closed cell sponge is made and used. This book is an attempt to bring this verboten subject out of the closet and perhaps maybe some day even into the classroom.

Chapter One will be a definition of terms. Before going into a brief description of what closed cell sponge is and how it is made, it is important that certain basic terms used in the industry are defined. Keep in mind when reading these definitions that they have often been misused and that you are probably accustomed to hearing them used in the wrong way. While your proper understanding of these terms is necessary, the most important point is that your technical communication with the factory be correct.

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A SHORT STORY ABOUT
SYNTHETIC RUBBER & PLASTIC


Refinery

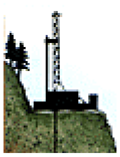
Refined Oil and
Refined Natural Gas


Polymerization
Plant

Synthetic Rubber and
Plastic Polymers


Manufacturers of
Rubber and Plastic
Products

The Manufacturing Cycle
for
Synthetic Rubber & Plastic


Crude Oil and
Crude Natural
Gas

Plastic Lawn Furniture • Rubber Tires • Plastic Bowls • Baby Bottle Nipples
Rubber Bands • Crosslinked EVA Foam
Neoprene Foam Wet Suits • Non-Crosslinked Polyethylene Foam

Rubber and
Plastic Products

PLASTIC	*THREE WELL-KNOWN FAMILIES OF POLYMERS*	RUBBER
POLYSTYRENE	⟷ *The Styrenic Family*	SBR STYRENE BUTADIENE RUBBER
POLYETHYLENE	⟷	EPDM ETHYLENE PROPYLENE

	The Polyolefin Family	DIENE MONOMER
PVC POLY VINYL CHLORIDE	*The Vinyl Nitrile Family*	NBR NITRILE BUTADIENE RUBBER

- The rubber and plastic within the same family are chemically compatible and, therefore, can be blended with each other in all ratios.
- After high shear blend mixing, the blend can be either crosslinked or not crosslinked.
- Blends that have a high rubber content almost always have to be crosslinked.
- Blends that have a high plastic content are usually not crosslinked.
- The word "*polymer*" is a generic chemical name for all synthetic rubber and plastic materials.

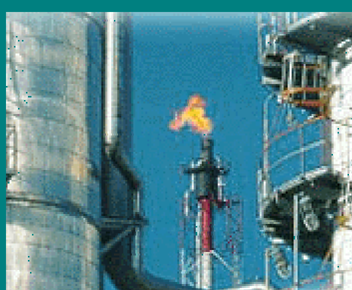
<table>
<tr><td colspan="3"><h2>Rubber or Plastic?</h2></td></tr>
<tr><td colspan="2">RUBBER:
"Rubber is what rubber does"</td><td></td></tr>
<tr><td></td><td><u>EXAMPLES:</u>
Automobile Tires
Rubber Bands
Baby Bottle Nipples</td><td><u>CHARACTERISTICS:</u>
• Tough, holds shape once formed even at hight temperatures
• Stretches, snaps back, good tensile
• Medically safe, soft, pliable, pure</td></tr>
</table>

PLASTIC:	
EXAMPLES: Clear, throw-away drinking glasses Clear, throw-away knives and forks Tupperware bowls, etc. Outside yard furniture	*CHARACTERISTICS:* • No stretch, not pliable, brittle, cracks easily • No great strength, can't withstand dishwasher heat • Better temperature range, no stretch • Lightweight, tough, inexpensive, weather-resistant

- The terms "rubber" and "plastic" are generic terms.
- They mean "rubberlike" or "plasticlike".
- The terms "crosslinked", "vulcanized" and "cured" mean basically the same thing.

Crosslinked or Not Crosslinked?

CROSSLINKED	NOT CROSSLINKED
The way an egg reacts with heat is an example of how a product reacts when it is crosslinked. Am egg has no shape or form before it is cooked (crosslinked). After it is cooked, it will keep whatever shape in which it has been cooked (vulcanized, cured, crosslinked).	The way a candle and a stick of butter melt and flow with heat are examples of how a plastic product reacts that has not been crosslinked. With relatively low heat they will soften and lose shape quickly. At room temperature they harden again. Because they are not crosslinked, this melting and hardening can be done over and over again to the same candle or piece of butter or plastic.

NATURAL GAS PROCESSING	produces ...	
	• Gases	Methane Ethane Propane Butane
OIL REFINING	produces ...	
	• Cracked Gases	CO, CO_2, H_2O Acetylene Ethylene Propylene Diolefins
	• Aromatics	Benzene Toluene Xylenes Naphthalene
	• Liquids	n-Paraffins Naphtha Gas - Oil Bottoms

RUBBER

The term rubber has now become generic. It is used to mean anything that is rubber-like. This includes some plastic materials which have rubber-like characteristics. Originally the term was used to define natural rubber. However now a whole family of synthetic rubbers and plastics are referred to, and correctly so, as rubber or rubber-like, for example, CR (chloroprene rubber, neoprene); SBR (styrene butadiene rubber); NBR (acrylonitrile butadiene rubber); and EPDM (ethylene propylene diene methylene). Certain plastics such as PVC (poly vinyl chloride) and polyethylene can be compounded and cured to have properties that are considered rubber-like. Generally speaking anything that has bounce, stretch, elongation, or memory (meaning that it returns to its original shape when the force of deformation is removed) is referred to as rubber or rubber-like.

CONSTRUCTION

All rubber products are manufactured in one of two constructions or types. The first type is normally called solid or dense rubber. The second type is normally referred to as cellular or sponge rubber.

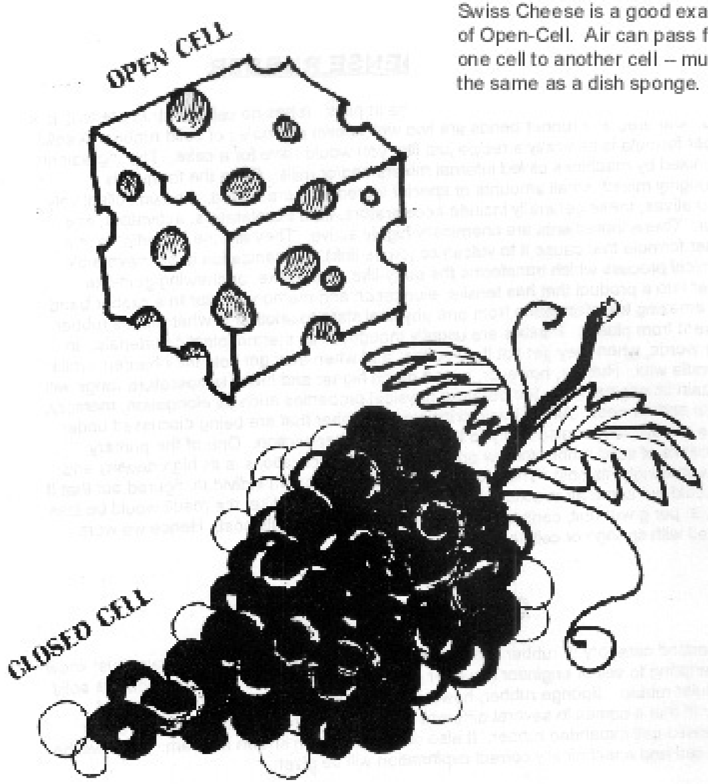
SOLID OR DENSE RUBBER

Solid or dense rubber is just what the name implies. It has no cellular structure to it; it is solid. Car tires and rubber bands are two well known examples of solid rubber. A solid rubber formula is basically a recipe just like you would have for a cake. The ingredients are mixed by machines called internal mixers and/or mills. Once the formula is thoroughly mixed, small amounts of special ingredients are added. Known collectively as curatives, these generally include accelerators, ultra accelerators, activators, and sulfur. These ingredients are chemically highly active. They are the ingredients in a rubber formula that cause it to vulcanize (cross-link). Vulcanization is an irreversible chemical process which transforms the putty-like, dough-like, or chewing gum-like rubber into a product that has tensile, elongation and memory similar to a rubber band. This amazing transformation from one physical state to another is what makes rubber different from plastic. Plastics are usually thought of as thermal plastic materials. In other words, when they get hot they soften, and when they get cold they harden similar to candle wax. Rubber, however, over a much higher and lower temperature range will maintain its original room temperature physical properties such as elongation, memory, tensile and harness. All the basic principles of rubber that are being discussed under dense or solid rubber also apply to the cellular rubber section. One of the primary drawbacks of solid rubber for low pressure sealing applications is its high density and, correspondingly, its cost. Therefore, years ago some bright individual figured out that if you could put some air in solid rubber and make it sponge-like, the result would be less material per given unit, consequently significantly reducing its cost. Hence we were blessed with sponge or cellular rubber.

CELLULAR RUBBER

The second category of rubber products is cellular rubber. The first thing we must know in attempting to sell or engineer a rubber product is whether the desired product is solid or cellular rubber. Sponge rubber, however, is a little more complicated than solid rubber in that it comes in several different forms. They are open-cell sponge rubber and closed-cell expanded rubber. It also comes in a form known as foam. Each will be discussed and a technically correct explanation will be given.

OPEN-CELL SPONGE RUBBER



Swiss Cheese is a good example of Open-Cell. Air can pass from one cell to another cell – much the same as a dish sponge.

Think of a bunch of grapes as a piece of Closed-Cell sponge rubber or plastic foam. Each grape is a complete cell. Break some, and the others are still intact.

Open-cell sponge rubber is made from many of the same ingredients used in making solid rubber. One ingredient, however, that is added to all cellular rubber formulas and is not in a solid or dense rubber formula is a powder common blowing agent. In the case of open-cell sponge rubber sodium bicarbonate (baking soda) is normally used. When the uncured sponge rubber is heated in a mold, it expands or rises like a cake under low pressure and the baking soda introduces a network of open cells. By open-cell we mean that each cell is connected to the other with an opening so that water, air or gas can pass through them similar to the way water is absorbed by a dish sponge. One outstanding characteristic of open-cell sponge rubber as compared to closed-cell sponge rubber is that open-cell has very good compression set. This is because the air rushes out of the open cells as the material is compressed. As soon as the pressure is released the air rushes back in and the material recovers to basically its full height. This is not so with closed cell as you will learn later.

Open-cell sponge rubber was the first type of cellular rubber made. It is becoming less of a factor in the cellular rubber gasketing market. It is being rapidly replaced by closed-cell sponge in just about every low pressure sealing application. In order to get open-cell sponge rubber to work as a seal you basically must compress the sponge down to a solid mass. In this way you minimize the ability of air, moisture, etc. from going through the cellular structure. As a result, greater thicknesses of open-cell sponge must be used where a much lesser thickness of closed-cell rubber would do a better job. All things being equal, it is also not practical to blow open-cell sponge to the very low densities to which you can blow closed- cell sponge. Therefore, the open-cell is usually more expensive. Remember, in designing an open-cell gasket to seal air or moisture you must compress the open cell sponge down to mass or to a semi-solid piece of rubber. However, in closed-cell applications all that is needed is surface-to-surface contact of the two sealing surfaces. From there the closed-cell structure of the expanded cellular rubber will function as an adequate seal.

EXPANDED CELLULAR RUBBER (CLOSED-CELL)

IS IT OPEN CELL OR CLOSED CELL?

SOME MANUFACTURERS LOOSELY REFER TO THEIR FOAMS AS CLOSED CELL EVEN THOUGH THEY ARE PARTIALLY OPEN CELL. THESE FOAMS WILL NOT PASS THE ASTM-D-1056 WATER ABSORPTION SPECS.

The technically correct term for closed cell sponge is expanded rubber. As we discussed above, the term sponge means a specific type of manufacturing process yielding an open-cell product. In closed-cell the term expanded cellular rubber means a specific manufacturing process which yields or produces a closed-cell product. The term sponge, it appears, is becoming generic to mean any cellular type material. A piece of closed-cell sponge rubber before it has been blown looks just like any solid or open-cell sponge rubber compound. It is mixed on the same type of equipment used to mix solid rubber but added to the expanded rubber formula, along with all the other classical compounding ingredients, is a powder which is a chemical blowing agent. This powder under heat and pressure decomposes and becomes soluble or mixes with the rubber and liberates or generates a gas called nitrogen which is inert. In other words it will not attack the rubber or degrade it. This process of the blowing agent becoming soluble in the rubber takes place in steel molds in a press under high pressure. This is commonly called the pre-cure cycle. The pre-cured material is then put into an oven and blown to its final size or stabilized at a size smaller than the size which came out of the press.

A detailed explanation follows later of the expanded closed-cell materials as they relate to Monmouth Rubber Corp. The material after it comes out of the oven is in bun form, usually a maximum of 2 1/2" thick. It is then aged and split into thinner sheets (as thin as 1/16") on a splitter. Inherent in all closed cell materials is some degree of shrinkage. This is as a result of the material being under tension during its manufacturing process. In other words, the gas pressure inside the material is greater than atmospheric pressure. This along with the type of rubber and the specific characteristics of the formula will result in more or less residual or after shrinkage. To compensate for this, some manufacturers including ourselves, hot house the material after it has been split. The splitting process in itself further relieve some tension. This hot housing or normalizing process which is done after the material is split is much the same type of thing as the pre-shrinking of cloth. The closed-cell sheets after hot housing are then fabricated or cut into shapes the same as you would any other sponge material. In some cases adhesive coatings are put on the sponge sheets before they are cut. In order to make closed- cell sheets continuous, they are butt spliced with adhesive into long rolls. They are then coated and fabricated into weather stripping or die-cut pieces.

The chief characteristic of closed-cell material that makes it unique as compared to open-cell material is its ability to restrict or resist to an absolute minimum the passage of moisture through the cellular structure of the sponge. The only valid test to separate truly closed cell materials from semi-closed cell materials or open-cell materials is the water absorption test in ASTM D 1056.

This unique physical property enables closed-cell sponge rubber to function in low pressure applications as an excellent seal replacing both open-cell sponge, foam, and solid rubber. Closed-cell products can be blown down to densities as low as 2# pcf and still function adequately as shock absorbing materials and as a dust, air, noise and moisture seal. Keep in mind the term density. It is important and is widely misunderstood and misused. An explanation follows later as to its real meaning and how to use it when engineering a closed-cell product.

Closed-cell expanded rubber is like a basket full of balloons that have all been glued together. The air inside of each individual balloon is locked in. If you severely squeeze or compress the closed-cell material you will force the gas or air out of the cells and the material will partially collapse which is technically referred to as compression set. However, given a relatively long period of recovery time the gas will permeate back into the cells and the closed-cell sponge rubber will recover some degree of its original thickness. Several major factors affecting the degree of recovery are the type of base polymer used, compounding (what ingredients are in the formula other than rubber), and the environmental conditions under which it was compressed. Compression set can be, if not properly engineered, a major problem with closed-cell materials. However, once it is understood and creatively used it can be turned into an asset. This will be discussed later in the book.

Another unique characteristic of closed-cell material is that it floats. It floats even when cut into teeny, weenie pieces. Therefore it is used in all sorts of water sports equipment such as life vests and water ski belts. Because you technically displace closed-cell and don't compress it, it also functions well as a shock absorbing material. In other words, when you squeeze closed-cell, rather than it going down flat to mass it bulges out at the sides similar to what would happen to a car tire if you were to put too much weight in the car. This ability of the air trapped in the cells to absorb shock and yet slowly recover makes closed-cell materials ideal for shock padding in sports equipment and wrestling mats. Closed-cell expanded rubber can be, and is made from natural rubber and just about every type of commercially available synthetic rubber and also from many plastics.

FOAM

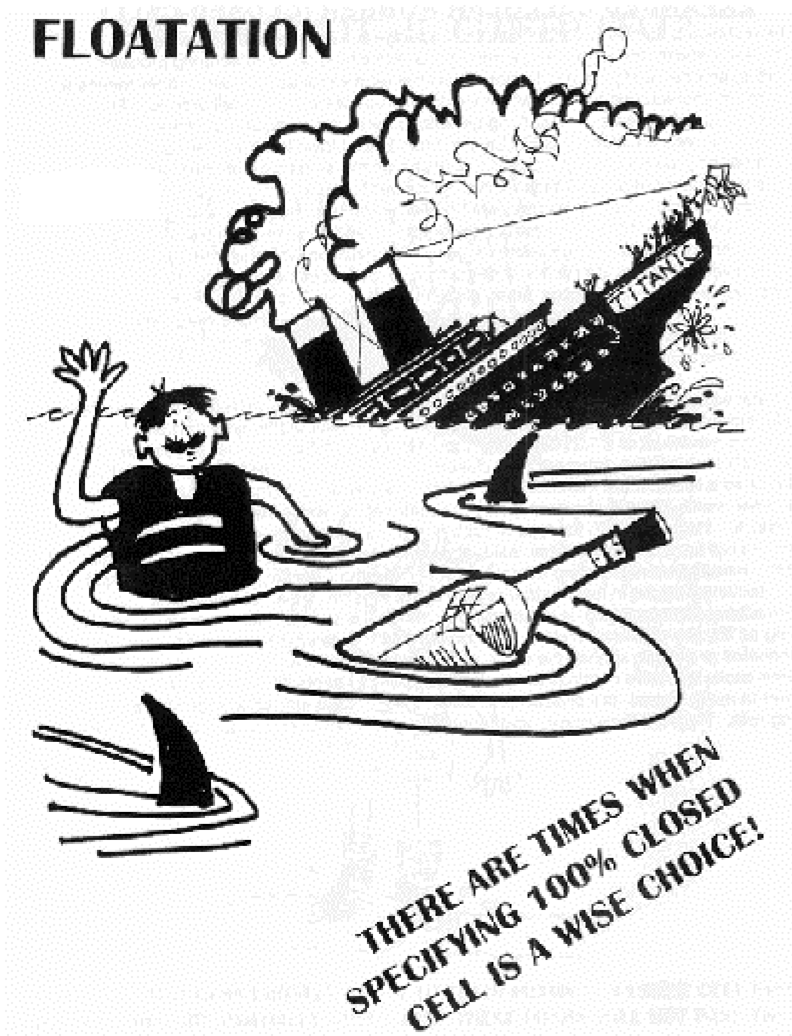
Once again the term foam denotes a specific manufacturing process whereby literally the material is foamed into a cellular structure. The most well known foams are polyurethane foam, latex foam, and PVC foam. Polyurethane foam is what is commonly used for the cushions on your chairs and sofas. Polyurethane foams are blown to densities as low as one pound per cubic foot. Latex rubber foams and PVC foams are blown to densities as low as 4 pounds per cubic foot.

Latex foam applications are rapidly being replaced by open-cell polyurethane foam and PVC. While polyurethane as a raw material is relatively expensive per pound, the one and two pound blown density urethane foams are inexpensive because of their low density.

All foams are basically open-cell. The term foam denotes inherently a low pressure process whereby the material is foamed onto a moving belt or into a contained area such as an open- top mold much the same way you would use a can of shaving cream. Once the material has jelled or set, you have a piece of foam. While there are some cells that are closed in any process, the predominant number of cells in a foamed product are open and none of these materials would pass the ASTM 5% weight water absorption test. This test is a basic requirement of all truly closed-cell materials.

The chief characteristic of polyurethane foam as a gasketing material that makes it so attractive throughout the industry is its low price. It is probably the lowest priced cellular product commercially available. Technically, however, many of the applications where I have seen polyurethane foam used, such as 1/8" gasketing and stripping, makes me wonder why any gasketing material is used at all.

WATER ABSORPTION



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SHOCK ATTENUATION (ABSORPTION)

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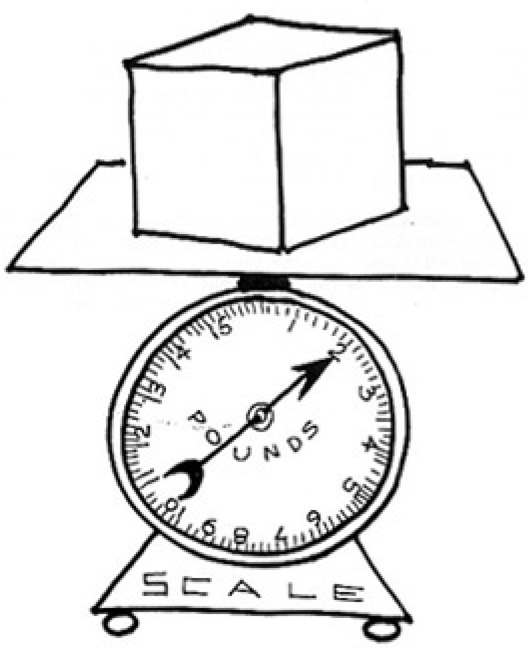
POLYMERS

A polymer for our purposes is a synthetic rubber or rubber-like material which is composed of two or more monomers. In other words, SBR which is a polymer, is made up of the monomers styrene and butadiene. They are polymerized or chemically reacted to form styrene butadiene rubber which is significantly different than either of the two base monomers from which it was made.

SPECIFIC GRAVITY

DENSITY IS WEIGHT . . .
DENSITY IS SPECIFIC GRAVITY . . .
DENSITY IS USUALLY EXPRESSED IN POUNDS PER CUBIC FOOT



One of the most important terms to fully understand in selling cellular materials is the term density (specific gravity). The term density and specific gravity mean the same thing. Yet these terms are probably the most misunderstood. By definition, for solids and liquids, specific gravity is the ratio of the weight or mass of a given volume of a substance to the weight or mass of water in the same given volume.

In English this means the following: A cubic foot of water weighs about 62 pounds. That is to say a container 12" wide x 12" long x 12" high, filled with water, weighs 62 pounds. If you filled the same square container with something else and weighed it, whatever that weight was would be its specific gravity.

If something has the same specific gravity as water than it is said to have a specific gravity of 1.0. If something weights 1 1/2 times the weight of water (93 pcf) then it is said to have a specific gravity of 1.5. Different polymers or rubbers have different specific gravities. For example, natural rubber has a specific gravity of .92 (57 pcf). In other words, it weighs less than 62 pcf. A substance that has a specific gravity of less than 1.0 will float in water. If you took a piece of natural rubber and put it in water it would float. Hence comes the term pure gum floating stock. SBR has a specific gravity of .94 (58.28 pcf). EPDM has a specific gravity of .86 (53.32 pcf). Neoprene has a specific gravity of 1.23 (76.26 pcf).

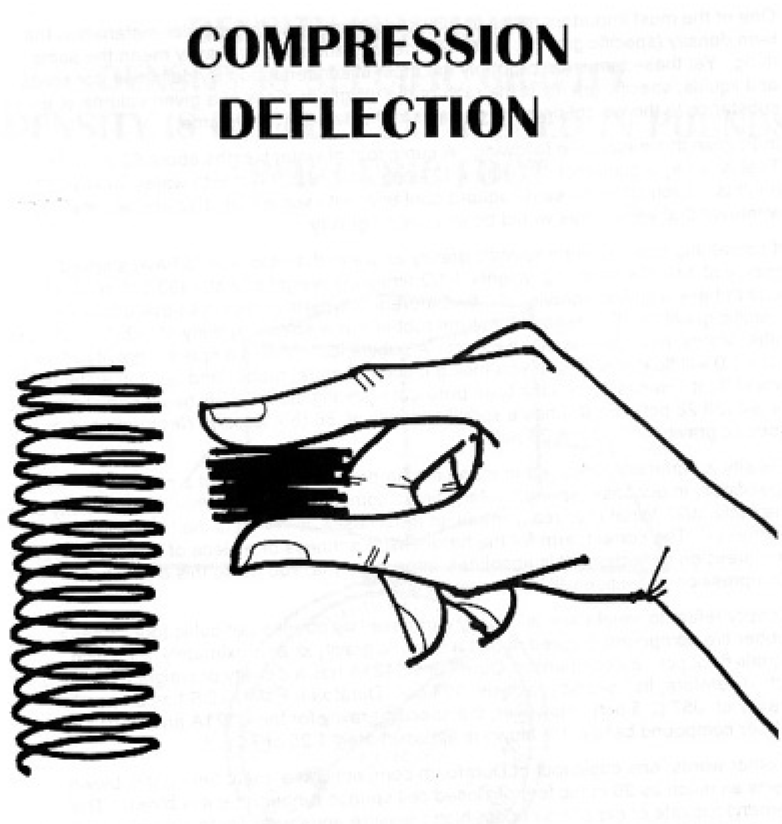
Density is commonly misused to mean the hardness or softness of a material, specifically in our case, sponge. Many times someone will ask "What is the density of the material?" What they really mean, in most cases, is "What is the hardness or softness?" The correct term for the hardness or softness of a piece of cellular rubber is compression deflection. It is absolutely imperative that you make this distinction. Compression deflection will be discussed later.

Density refers to weight and is usually expressed as pounds per cubic foot. After a rubber tire compound is cured, it has a specific gravity of approximately 1.1 which equals 68.2 pcf. By comparison Durafoam C121A has a density or weight of about 6 pcf. Therefore, its specific gravity is .097 pcf. Durafoam C191XLDS has a specific gravity of .057 (3.5 pcf). However, the specific gravity for the C121A and C191XLDS rubber compound before it is blown is approximately 1.25 or 78 pcf.

In other words, one cubic foot of Durafoam compound in a mold before it is blown yields as much as 20 cubic feet of closed cell sponge rubber after it is blown. This tremendous rate of expansion under high pressure and the ability to control it and make a uniform product is what makes closed cell expanded materials so unique and so hard to make. As a result there are relatively few manufacturers of this material throughout the world.

Once again remember specific gravity is the same as density and densitv is not a measure of the hardness or softness of a cellular product. Balsa wood, for example, is very light yet very firm. Balsa wood has a very low density but a very high hardness. A classical example of the incorrect use of the word density to mean softness is to say that balsa wood has a very soft density. It is just as incorrect to use the term density to describe the softness or hardness of cellular rubber but most of all when communicating with the factory it is technically confusing.

COMPRESSION DEFLECTION



HOW SOFT OR FIRM IS A PIECE OF SPONGE RUBBER OR PLASTIC FOAM?

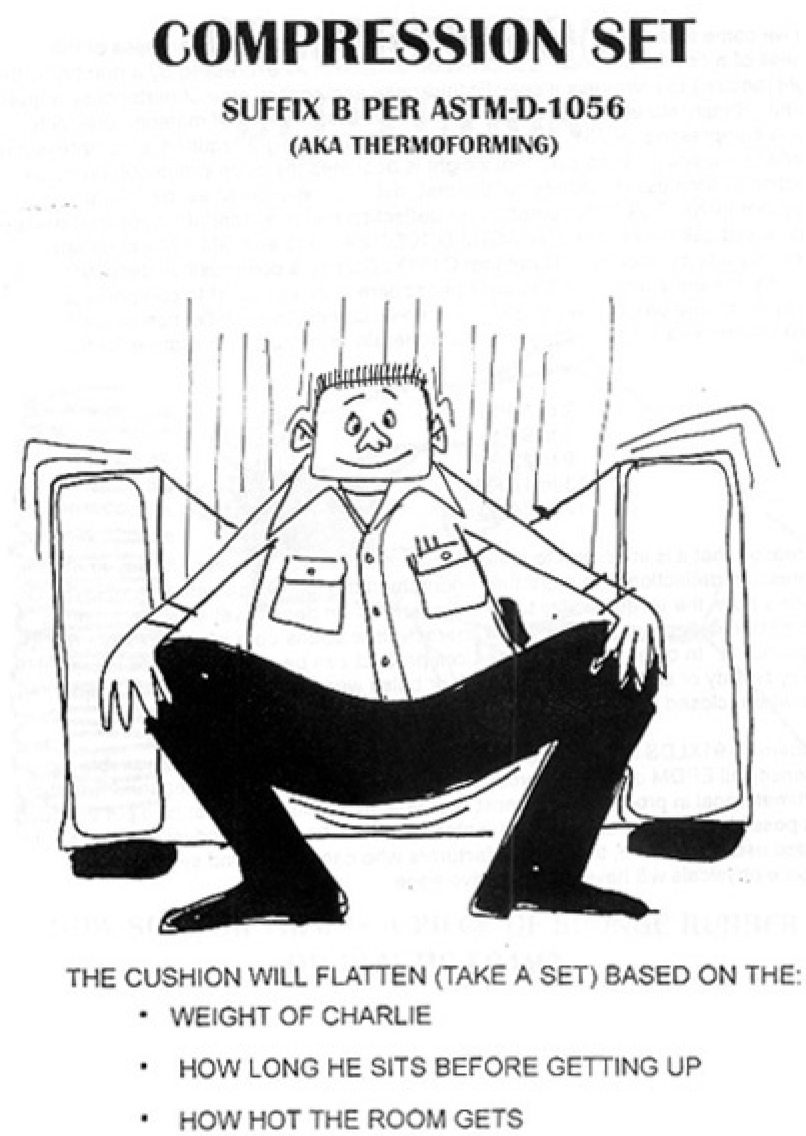
Now we come to the term which means the measure of either the hardness or the softness of a cellular product. Compression deflection as expressed by a number is the weight required to compress a specific thickness and square area of material by a given amount. Simply stated it means this: A one inch square piece of material, one inch thick, is compressed by 25% (down to 3/4" thick). The weight required to compress it is recorded on a scale. Whatever that weight is becomes the appropriate compression deflection or firmness or softness of the material. It is referred to as the PSI (pounds per square inch). This 25% compression deflection test is a standard basis of measure for all closed cell materials under ASTM D 1056, SAE J18 and GM 1379 and many others. By way of reference. Durafoam™ C191XLDS has a compression deflection of 3 PSI. That means a weight of 3 pounds per square inch is needed to compress a 1" thick by 1" square piece down to 3/4". The basic compression deflection range of closed cell materials follow along with the generally referred nomenclature for that range.

2 to 5 PSI	SOFT
5 to 9 PSI	MEDIUM
9 to 13 PSI	FIRM
13 to 17 PSI	EXTRA FIRM
17 to 24 PSI	VERY FIRM

One reason that it is important to understand the difference between density and compression deflection is to more fully understand the following statement. Closed cell materials have the unique ability to be extremely low in density yet extremely high in compression deflection. This physical characteristic opens up a whole area of creative compounding. In other words, a closed cell product can be made very light in weight yet very boardy or stiff like a piece of cork or balsa wood. This is one of the major areas where closed cell material gets its competitive edge over other materials.

Durafoam™ C191XLDS is an example of this. It is the only commercially available extra low density all EPDM closed cell product. This is important if you understand fully that the ultimate goal in producing the most cost effective cellular product is to put as much air as possible into each cubic foot of material and still have the product function for its intended use. Therefore, those manufacturers who can do this and still maintain adequate physicals will have a competitive edge.

COMPRESSION SET



Compression set results are expressed normally by a percentage figure maximum. For example, suffix requirement "B" under ASTM D 1056-73 has a compression set requirement of 25% maximum. In order to pass this test, the material must have less than 25% compression set. Compression set results can become very confusing in that they are calculated different ways under different methods of test. For example, when a 1" piece of closed cell sponge is compressed to 1/2" for a given period of time, after releasing the pressure and immediately measuring the thickness of the material, if the measurement is 3/4" then basically the sample has taken a 1/4" compression set. If you calculate this 1/4" on the total original thickness of the sample, you will get a result of 25% (.25" ÷1.00"=25%). If you calculate this 1/4" based on the amount of compression, which in this case was 1/2", you will then get a compression set of 50% (.25" ÷ .50"=50%). Further the time of recovery before the measurement is made varies with different test requirements. The important point to remember is that there is no one method of measuring compression set. Therefore the exact method of test must be known in order to be sure that the results are being compared on an equal basis with competitive materials. When replacing open cell sponge with closed cell, special care must be taken to fully evaluate the thickness required in the closed cell material. Normally if the thickness being used in open cell is replaced with the same thickness in closed cell, the closed cell material will take an excessive compression set. This is because open cell must be compressed by a much greater amount in order to form a seal. It is generally recommended that a closed cell product not be compressed more that 33% in its intended application over extended periods of time. Careful examination and consideration of the application involved will usually result in thickness' being specified where no more than 5% or 10% compression is required.

Remember in a closed cell product, in order to effectuate a positive seal all that is needed is surface to surface contact between the mating surfaces due to the fact that the closed cell material is relatively impervious. Many times the thickness of the closed cell specified is greater than it need be which results in a higher unit cost per gasket and in the gasket taking an excessive compression set. Theoretically compression set is directly related to state of cure. However, in cellular materials the amount of compression set in a product is further complicated by the unique properties of expanded rubber such as cell size, density, and compression deflection. Generally speaking, the denser the material, the less set it will take. The firmer it is, the less set it will take. Conversely the lower the density, the more set it will take. The softer it is, the more set it will take. Incremental increases in temperature above room temperature have a profound effect on compression set way out of proportion to their unit increase. Specific applications relating to compression set should be discussed in detail with the factory.

COMPRESSION SET

Perhaps one of the most misused requirements on cellular rubber specifications is the fluid immersion test. By that I mean, as a practical matter, very few applications where cellular rubber products are used require that the material have resistance to gasoline or oil other than in a very casual and insignificant way. Therefore, special care should be taken to question customer requirements in detail for fluid immersion to determine if the immersion required is applicable for the application or use. We have been successful at Monmouth Rubber in pointing out to numerous customers where they had severe oil requirements as part of their specifications, that by deleting that requirement, significant savings could be realized without any compromise whatsoever on product performance. One typical example is a customer that makes hot air ducts. The print which specified the duct gasketing had a requirement for oil immersion. It was pointed out to the customer that this particular aspect of the spec was not relevant to the application. The customer agreed and it was deleted from the print with a savings of 25% on the cost of the gasket with no decrease in product performance. Often times theses specifications find their way onto subsequent prints within a company and then company to company mostly due to the basic lack of knowledge in industry on how to properly specify a cellular rubber product.

SPECIFICATIONS

The bible specification for flexible closed cell materials is ASTM-D-1056, the latest revision being -91. This specification is titled "SPONGE AND EXPANDED CELLULAR RUBBER PRODUCTS." Basically all other closed cell specifications are an off shoot in one form or another of ASTM D1056. A thorough understanding of ASTM-D-1056 will go a long way toward clearing up a lot of the confusion which exists in the field when attempting to sell and/or specify . closed cell products. For example, GM 1379 and SAE J18 are essentially a copy of ASTM-D-1056. Other typical closed cell specs are Mil-R-6130, Mil-C-3133 and Mil Std. 670. These specs are also basically off shoots of ASTM-D-1056. There are basic physical requirements that all closed cell rubbers must have in order to meet ASTM-D-1056.

These requirements are as follows:

1.) A hardness or compression deflection. For example, 2 to 5 PSI.
2.) Oven Aging with a resultant change in original physical limits being ± 30%.
3.) Water absorption maximum by weight 5% for the higher density materials and 10% for the lower density materials.

These three basic requirements are then modified by suffix letters. Some of the suffix letters are specific as to their requirements. Others carry the notation "Values to be arranged between the supplier and the purchaser." A detailed understanding of what these requirements are can be had by studying ASTM-D-1056.

One overriding factor that causes probably 80% of the confusion on understanding ASTM D 1056 is the grade numbers and their meaning changes under the different year revisions of the spec. As a member of the ASTM D 1056 committee that writes and reviews this specification, we were responsible for compiling an ASTM cross reference chart for the years as noted, a copy of which is on the next page. By Dialing Durafoam Direct at 888-FOAM-888 Ext. 12, we can help you walk through any confusion or misunderstanding that still exists or in any other area that you have a question.

FLUID IMMERSION

FLUID IMMERSION

ASTM-D-1056-91

MAXIMUM ALLOWABLE INCREASE IN WEIGHT

GRADE A - NONE REQUIRED
GRADE B - 50% MAXIMUM
100% MAXIMUM WHEN OVER 10 PCF
GRADE C - 150% MAXIMUM
250% WHEN OVER 10 PCF

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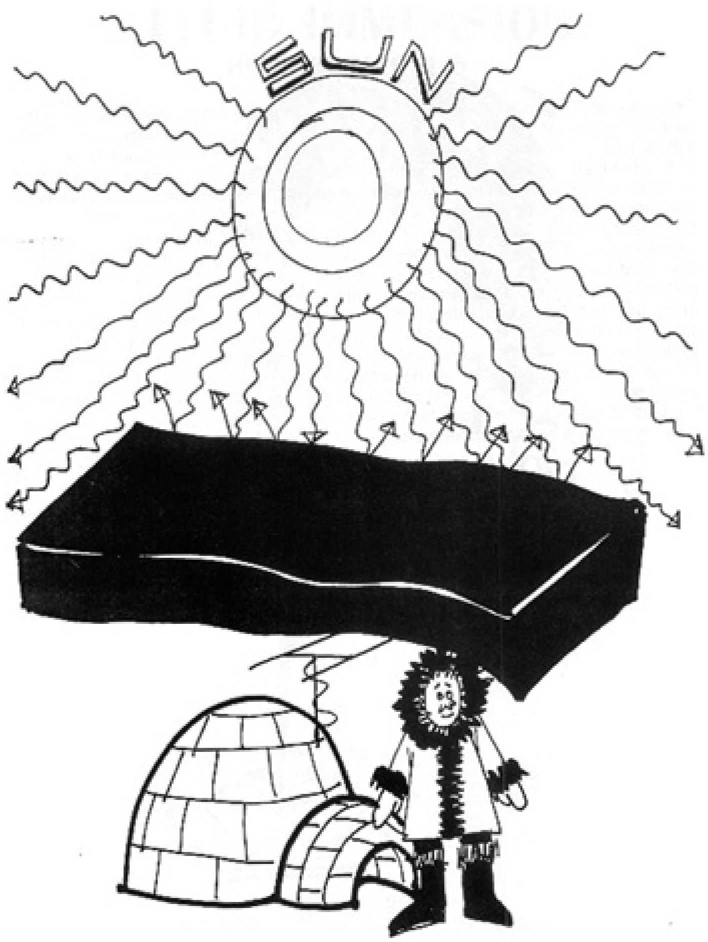
INSULATION

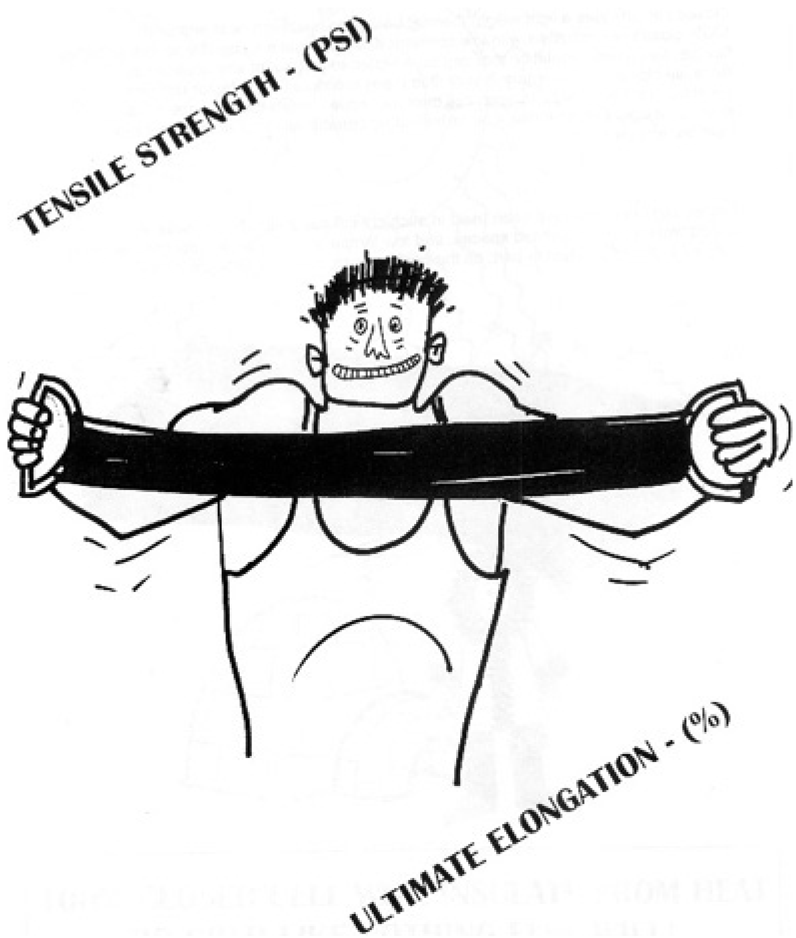


100% CLOSED CELL WILL INSULATE FROM HEAT OR COLD LIKE NOTHING ELSE WILL!

Closed-cell provides a lightweight thermal barrier against both heat and cold. 100% closed-cell materials with low constant K-factors make it possible to design highly flexible, thin gauge insulation that can be adapted to just about any application. Because closed-cell materials absorb little if any moisture, the K-factor remains constant. In other words in open-cell material, while it might initially have a low K-factor, it would immediately lose its insulating capabilities once it absorbed moisture from the atmosphere.

Closed-cell materials have been used in such critical applications as submarines, chilled water lines in confined spaces, and low temperature footweat applications where survival is based, at least in part, on the performance of the insulating material.

TENSILE STRENGTH & ELONGATION



Tensile strength is the maximumtensile stress which a mterial is capable of developing. It is the force per unit of the original cross-sectional area which is applied at the time of rupture of a speciment, and is known variously as "breaking load," "breaking stress," and "ultimate tensile strength." It is expressed in pounds per square inch or kilograms per square centimeter of cross-sectional area of the unstressed speciment. See ATSM Methods D412 qnd E6.

Tensile stress is the force per unit of original cross-sectional area required to stretch the specimen to a stated elongation. It is often designated in rubber technology by the term "modulus." See ASTM Methods D412.

Elongation is the extension between bench marks produced by a tensile force applied to a specimen, expressed as a percentage of the original distance between the marks. Ultimate elongation is the elongation at the moment of rupture. If a 1-inch length is marked on a specimen and it is stretched until the bench marks are 7 inches apart, the elongation is

7 - 1 + 6 inches, or 600%. See ASTM Methods D412.

A rubber band is an example of a product that has high tensile and high elongation.

SHOCK ATTENUATION (ABSORPTION)

Hitting yourself on the head with a hammer with nothing on your head to protect it is why materials are used to attenuate or absorb shock. When you are packaging people, it is used for such things as helmets, knee pads, and shoulder pads. For products, it is used for such things as packaging for computers, instrument cases for delicate instruments, and so on. With a hard surfaced helmet on your head lined with the proper closed cell material, the strike of the same hammer with the same amount of force, if properly designed, would not cause life-threatening injuries.

Closed cell materials perform this function more efficiently than other types of materials. In shock attenuation, controlled compression and controlled recovery, impact after impact, delivers a knockout punch. For closed cell construction of a material combined with the proper choice of polymer, density, and compression deflection effectively absorbs "G" forces in a predictable manner.

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MONMOUTH RUBBER & PLASTICS CORP.

WHAT WE MAKE AND HOW WE MAKE IT!

While we make a comprehensive line of solid and sponge rubber and plastic products, our area of specialization is expanded cellular rubber and plastic products. Certain steps in the manufacture of closed cell rubber and plastic are common to the manufacture of most closed cell products. Bales of synthetic rubber and plastic resin and a variety of different compounding ingredients such as carbon black, clay and process oil are mixed together in an internal mixer . Added to these ingredients are curatives which are chemically very active.

Once cured or crosslinked, the rubber or plastic cannot be melted or reverted back to its original form. It retains the shape to which it has been cured or crosslinked. A classical example of this is a car tire. If a car tire were made of non-crosslinked plastic, it would soften and melt once it reached the high temperatures tires are exposed to during their normal wear and tear.

Once these chemically active curatives are put into a rubber compound, the process variables that go into making the product must be controlled very closely or else this chemical reaction known as vulcanization will take place too soon and the product will be ruined. Ideally there should be no chemical activity taking place until the mixed rubber is put into the mold and the rubber has had a chance to flow into all the crevices and contours of the mold. One thing that makes closed cell rubber so difficult to make is that along with the cure curve which takes place while the rubber is in the mold, there is also introduced a blow curve by virtue of the fact that when you make closed cell rubber you add to the formula powder with the consistency of flour which is called a blowing agent. This powder under heat and pressure decomposes and releases nitrogen gas to form the closed cell structure of the material.

After the closed cell is mixed, it is put into a mold for curing which is commonly referred to as the pre-cure stage. The mold is put into a high tonnage press under high pressure and cured at a variety of temperatures for differing periods of time, depending on the compound. During this stage the blowing agent decomposes and releases nitrogen gas which becomes soluble in the rubber. At this point the pressure of the press must be greater than the pressure exerted by the expanding nitrogen gas. It is for this reason that extremely large and expensive presses are needed to prevent the pressure generated inside the mold from opening the press.

Keeping the cure curve and the blow curve relatively parrell during all phases of curing and blowing is basic to the proprietary process of manufacturing closed cell. If the blow curve gets to far of the cure curve you loose all of the gas that is generated an the closed cell product flops like a cake in the oven. If the cure curve gets too far ahead of the blow curve, then the material is cured too tight and will come out hard and small and not expand to its proper size. While this may sound relatively easy, practical experience has shown that it is a most difficult process to control day to day with all the process variables that go with running these types of materials. Relatively speaking there are only a few manufacturers of closed cell in the country today.

After the closed cell material is fully cured and the gas is fully decomposed, the press is opened and the closed cell buns literally explode out of the molds into a size somewhat larger than their final size. This process is commonly referred to as the jump blow process. Using this process, which is one that most closed cell manufacturers use, you are not able to obtain very low densities such as 2#, 3# or 4# per cubic foot. Monmouth uses the "jump blow process" for some of our products.

From the press these buns of closed cell then go into an oven and are final cured and stabilized. This process is sometimes referred to as a post cure. From here the buns are split in to thin sheets, hot housed and fabricated in a variety of ways which will be discussed later.

THE DURAFOAM™ PROCESS

Developed by Monmouth Rubber in the late 1960's, the Durafoam™ process is proprietary and unique. It has resulted in several "developed here first" products over the last 25 years.

The Durafoam™ process is a two to four stage process of partial curing and blowing in stages in a combination of both presses and ovens. Under this proprietary process large amounts of blowing agents are used along with sophisticated and complex cure systems. The process is an extremely sensitive one which allows extremely low densities and fine cell structure in the final product in a variety of polymers, both rubber and plastic.

One product developed by Monmouth with the Durafoam™ process is Durafoam™ P191XLDS, 100% EPDM low density. Developed in 1976 it was the first 3 pound commercially available EPDM material The proprietary Durafoam™ process allows us to make buns as large as 60" x 100" which we believe to be the largest press-cured buns available in the world today.

The above two processes go to make up what is known as our Polymer Processing department. From here the material goes to our Splitting department. The material is split into a variety of thickness' as low as .025".

Choose the "Products" button above for a brief overview of our product line.

CONCLUSION

The future is extremely promising for a company such as ours. It has been proven time and time again that large companies are neither capable of nor interested in the kind of high technology, flexibility and service that is needed to properly service industrial cellular closed cell customers. Our steady growth is a testimony to our ability to meet this challenge. Our continued growth will provide for us the necessary base to develop the cellular products for the applications of tomorrow.

