RUBBER HANDBOOK
FOR MOLDED, EXTRUDED, LATHE CUT AND CELLULAR PRODUCTS

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FOREWORD

Rubber manufacturers and their customers have long recognized the need for a "universal language" by which design engineers can express their exact requirements and specifications for rubber parts.

In designing rubber parts, engineers have always had the problem of specifying requirements in terms sufficiently clear to enable the manufacturers to determine with a reasonable degree of accuracy what is actually described in terms of performance, tolerance and service characteristics.

A portion of this problem, namely a standard means for designating rubber materials, has in large part been solved. By using the charts, symbols and definitions developed jointly by the American Society for Testing and Materials and the Society of Automotive Engineers (presently under the jurisdiction of SAE) and approved and published as ASTM D-2000 and as SAE J-200 (or ASTM D-1056 and SAE J-18 for sponge and expanded cellular products), design engineers are able to place on their drawings appropriate symbols and numbers to express precise material requirements. The rubber manufacturers, in turn, by referring to the same basic ASTM or SAE data, can interpret accurately what the engineers have specified. With the use of these charts approaching complete acceptance, error and misunderstanding of material requirements have been substantially reduced.

Thus, part of the "universal language" has been established and is in common usage. There remains, however, a large area to be covered. This area includes the means of specifying engineering and quality conformance requirements. This Handbook is the effort of the molded, extruded, lathe-cut and cellular rubber industries to provide engineers with a uniform method of stating these requirements in a manner their suppliers can approach with the same certainty of understanding.

Rubber manufacturers seek in this handbook to establish a language which will enable engineers to express, on their drawings, requirements which will give them what they need, but not more than they need. To accomplish this, we set up the "language" on the following pages in the form of symbols, charts and definitions.

The manufacturing techniques, capabilities, limitations and problems are different for molded rubber parts than for extruded rubber parts or lathe-cut or cellular (expanded and sponge) rubber parts. Each is treated in a separate chapter with its own charts and definitions. Quality conformance is treated in a separate section.

The use of this handbook will lead to a better understanding between Design Engineers, Purchasing Departments and Inspection and Quality Control Departments of the users of these rubber products and the Technical, Production and Quality Control Departments of the rubber companies.

The *expressions used* throughout this Handbook are the standard terminology used in the rubber manufacturing industry. It will be noted that the chapters on molded, extruded, lathe-cut and cellular (expanded and sponge) products are specifically pointed towards an exposition of the manufacturing techniques, capabilities and limitations of these areas. A method of prescribing the technical aspects of the quality desired is presented in these sections, (qualitative standards).

Technical Committees recognize that acceptable quality level (AQL) is a *quantitative* standard and is applicable only after the engineering qualitative standards have been set up between the producer and the customer. This fourth edition includes a section on quality conformance standards. An attempt has been made to define and present uniform quality conformance practices applicable to the rubber products described in this Handbook. This section is designed to aid customers in setting up acceptable quality levels which are also practical for the rubber suppliers to meet.

The correct quality level (not too high, not too low) is necessary, as it is with engineering standards, to make a practical product. The Committee drafting this fourth Handbook revision intended that it would be the most useful and most widely accepted manuscript that is possible. To accomplish this end we solicited the advice of knowledgeable people associated with American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM), International Standards Organization (ISO) and the Society of Automotive Engineers (SAE).

Recognizing the possible need for metric values we have printed all tables in both English and metric units. We have incorporated the use of preferred numbers as described in the ISO R-3 and R-17 documents wherever possible. We have applied the rules for the use of the International System of units as outlined in the ISO recommendations R-1000. Some typical examples of the use of these SI units are found in the "Standards for Rubber-to-Metal Adhesion" and the "Standards for Static and Dynamic Load Deflection Characteristics" in the chapter on molded rubber products.

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PURPOSE AND SCOPE

The purpose of this section is to provide a method for standardizing drawing designations for specific design requirements of molded rubber products. Information set forth on the pages that follow should be helpful to the design engineer in setting up realistic specifications for molded rubber products.

The use of proper symbols by designers in specifying on drawings exactly what is required is a matter of paramount importance. Proper use of these symbols by both product designer and rubber manufacturers will result in a common understanding of the design requirements which must be engineered into molded rubber products. To assure a uniform method for use on drawings and in specifications, the symbols on the following pages have been standardized by the Rubber Manufacturers Association for use in the molded rubber field.

Although rubber manufacturers can produce products to high standards of precision, they welcome the opportunity to suggest modifications which would reduce costs. The purchasers of molded rubber products can assist to this end by furnishing the manufacturers with details covering the application of their parts.

The scope of this section presents to the user the tolerances and standards the rubber manufacturers are normally able to maintain.

NOTE: Where the term "Rubber" is used in this section, it is intended to include the more common synthetic elastomers as well as natural rubber. Text reference is to material commonly measured with a Shore "A" durometer. The applicability of this information to thermoplastic rubbers has not been determined.

STANDARDS FOR TOLERANCES

FACTORS AFFECTING TOLERANCES

Introduction

The purpose of this section is to list some of the factors affecting tolerances. In general, the degree of reproducibility of dimensions depends upon the type of tooling and rubber used, and the state of the art.

Discussion of Factors Affecting Tolerances

There are many factors involved in the manufacturing of molded rubber products which affect tolerances. Since these may be peculiar to the rubber industry, they are listed here.

Shrinkage

Shrinkage is defined as the difference between corresponding linear dimensions of the mold and of the molded part, both measurements being made at room temperature. All rubber materials exhibit some amount of shrinkage after molding when the part cools. However, shrinkage of the compound is also a variable in itself and is affected by such things as rubber batch variance, cure time, temperature, pressure, post cure, and inserts, if any. The mold designer and the compounder must estimate the amount of shrinkage for the selected compound and incorporate this allowance into the mold cavity size. Even though the mold is built to anticipate shrinkage, there remains an inherent variability which must be covered by adequate dimensional tolerance. Shrinkage of rubber is a volume effect. Complex shapes in the molded product or the presence of inserts may restrict the lineal shrinkage in one direction and increase it in another. The skill of the rubber manufacturer is always aimed at minimizing these variables, but they cannot be eliminated entirely.

Mold Design

Molds can be designed and built to varying degrees of precision, but not at the same cost. With any type of mold, the mold builder must have some tolerance, and therefore, each cavity will have some variance from the others. Dimensional tolerances on the product must include allowances for this fact. The accuracy of the mold register must also be considered. This is the matching of the various plates of the mold that form the mold cavity. Register is usually controlled by dowel pins and bushings or by self-registering cavities. For molds requiring high precision in dimensions and register, the design work and machining must be more precise and the cost of the molds will be greater than one with commercial requirements.

Trim and Finish

The objectives of trimming and finishing operations are to remove rubber material — such as flash, which is not a part of the finished product. Often this is possible without affecting important dimensions, but in other instances, some material is removed from the part itself. Where thin lips or projections occur at a mold parting line, mechanical trimming may actually control the finished dimension.

Inserts

Most insert material (metal, plastic, fabric, etc.) have their own standard tolerances. When designing inserts for molding to rubber, other factors must be considered, such as fit in the mold cavities, location of the inserts with respect to other dimensions, proper hole spacing to match with mold pins, and the fact that inserts at room temperature must fit into a heated mold. In these matters, the rubber manufacturer can be of service in advising on design features.

Distortion

Because rubber is a flexible material, its shape can be affected by temperature. Distortion can occur when the part is removed from the mold or when it is packed for shipment. This distortion makes it difficult to measure the parts properly. Some of the distortion can be minimized by storing the part as unstressed as possible for 24 hours at room temperature. Some rubber will crystalize (stiffen) when stored at low temperature and must be heated to above room temperature to overcome this condition.

Environmental Storage Conditions

Temperature: Rubber, like other materials, changes in dimension with changes in temperature. Compared to other materials the coefficient of expansion of rubber is high. To have agreement in the measurement of products that are critical or precise in dimension, it is necessary to specify a temperature at which the parts are to be measured and the time required to stabilize the part at that temperature.

Humidity: Some rubber materials absorb moisture. Hence the dimensions are affected by the amount of moisture in the product. For those products which have this property, additional tolerance must be provided in the dimensions. The effect may be minimized by stabilizing the product in an area of controlled humidity and temperature for a period not less than 24 hours.

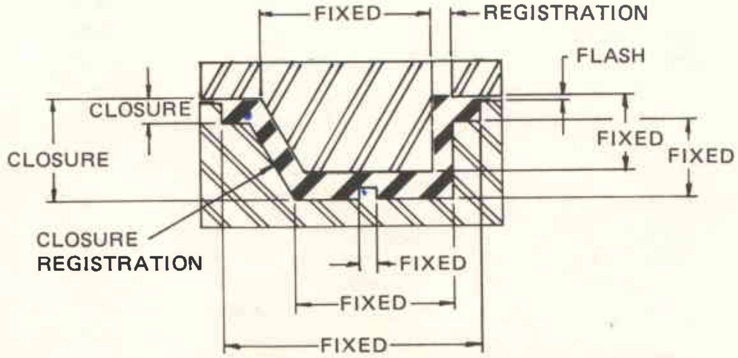
Dimension Terminology

The following will provide a common terminology for use in discussing dimensions of molded rubber products, and for distinguishing various tolerance groupings:

Fixed Dimension: Dimensions not affected by flash thickness variation. (Mold Closure) See Figure #1.

Closure Dimensions: Dimensions affected by flash thickness variation. (Mold Closure) See Figure #1.

Figure 1



In addition to the shrinkage, mold maker's tolerance, trim and finish, a number of other factors affect closure dimensions. Among these are flow characteristics of the raw stock, weight, shape of preform and molding process.

While closure dimensions are affected by flash thickness variation, they are not necessarily related to basic flash thickness. If a manufacturer plans to machine or die trim a product, the mold will have a built-in flash, which will be thicker than if hand deflashing or tumble trim were to be employed. Thus products purchased from two sources could have different basic flash thickness at the parting line and yet meet drawing dimensions.

There is usually a logical place for the mold designer to locate the parting line for best dimensional control and part removal. If the product design limits this location, an alternate mold construction will be required, which may affect the tolerance control on the product, and may, in some cases, increase the cost of the mold.

Registration Dimension: Dimensions affected by the matching of the various plates of the mold that form the mold cavity. Register is usually controlled by dowel pins and bushings or by self-registering cavities.

TOLERANCE TABLES

The tables on page 5 are presented as a guide in selecting tolerances.

When applying tolerances the following rules should be kept in mind.

(1) Fixed dimension tolerances apply individually to each fixed dimension by its own size.

(2) Closure dimension tolerances are determined by the largest closure dimension and this single tolerance is used for all other closure dimensions.

(3) Fixed and closure dimensions for a given table do not necessarily go together, and can be split between tables.

(4) Tolerances not shown should be determined in consultation with the rubber manufacturer.

(5) Care should be taken in applying standard tolerances to products having wide sectional variations.

Table 1

STANDARD DIMENSIONAL TOLERANCE TABLE — MOLDED RUBBER PRODUCTS
DRAWING DESIGNATION "A1" HIGH PRECISION

Size (Inches)	Fixed	Closure	Size (Millimeters)	Fixed	Closure
Above Incl.			Above Incl.		
0 - .40	± .004	± .005	0 - 10	± .10	± .13
.40 - .63	.005	.006	10 - 16	.13	.16
.63 - 1.00	.006	.008	16 - 25	.16	.20
1.00 - 1.60	.008	.010	25 - 40	.20	.25
1.60 - 2.50	.010	.013	40 - 63	.25	.32
2.50 - 4.00	.013	.016	63 - 100	.32	.40
4.00 - 6.30	.016	.020	100 - 160	.40	.50

METRIC

Drawing Designation "A1" is the tighest tolerance classification and indicates a high precision rubber product. Such products require expensive molds, fewer cavities per mold, costly in-process controls and inspection procedures. It is desirable that the exact method of measurement be agreed upon between rubber manufacturer and customer, as errors in measurement may be large in relation to the tolerance.

Some materials, particularly those requiring post curing, do not lend themselves to Drawing Designation "A1" tolerances.

Table 2

STANDARD DIMENSIONAL TOLERANCE TABLE — MOLDED RUBBER PRODUCTS
DRAWING DESIGNATION "A2" PRECISION

Size (Inches)	Fixed	Closure	Size (Millimeters)	Fixed	Closure
Above Incl.			Above Incl.		
0 - .40	± .006	± .008	0 - 10	± .16	± .20
.40 - .63	.008	.010	10 - 16	.20	.25
.63 - 1.00	.010	.013	16 - 25	.25	.32
1.00 - 1.60	.013	.016	25 - 40	.32	.40
1.60 - 2.50	.016	.020	40 - 63	.40	.50
2.50 - 4.00	.020	.025	63 - 100	.50	.63
4.00 - 6.30	.025	.032	100 - 160	.63	.80
6.30 & over - To find fixed dimensional tolerances multiply by 0.4%.			160 & over - To find fixed dimensional tolerances multiply by 0.4%.		

METRIC

Drawing Designation "A2" tolerances indicate a precision product. Molds must be precision machined and kept in good repair. While measurement methods may be simpler than with Drawing Designation "A1", careful inspection will usually be required.

Table 3

STANDARD DIMENSIONAL TOLERANCE TABLE — MOLDED RUBBER PRODUCTS
DRAWING DESIGNATION "A3" COMMERCIAL

Size (Inches)	Fixed	Closure	Size (Millimeters)	Fixed	Closure
Above Incl.			Above Incl.		
0 - .40	± .008	± .013	0 - 10	± .20	± .32
.40 - .63	.010	.016	10 - 16	.25	.40
.63 - 1.00	.013	.020	16 - 25	.32	.50
1.00 - 1.60	.016	.025	25 - 40	.40	.63
1.60 - 2.50	.020	.032	40 - 63	.50	.80
2.50 - 4.00	.025	.040	63 - 100	.63	1.00
4.00 - 6.30	.032	.050	100 - 160	.80	1.25
6.30 & over - To find fixed dimensional tolerances multiply by 0.5%.			160 & over - To find fixed dimensional tolerances multiply by 0.5%.		

METRIC

Drawing Designation "A3" tolerances indicate a "commercial" product and will normally be used for most products.

Table 4

STANDARD DIMENSIONAL TOLERANCE TABLE — MOLDED RUBBER PRODUCTS
DRAWING DESIGNATION "A4" NON CRITICAL

Size (Inches)	Fixed	Closure	Size (Millimeters)	Fixed	Closure
Above Incl.			Above Incl.		
0 - .40	± .013	± .032	0 - 10	± .32	± .80
.40 - .63	.016	.036	10 - 16	.40	.90
.63 - 1.00	.020	.040	16 - 25	.50	1.00
1.00 - 1.60	.025	.045	25 - 40	.63	1.12
1.60 - 2.50	.032	.050	40 - 63	.80	1.25
2.50 - 4.00	.040	.056	63 - 100	1.00	1.40
4.00 - 6.30	.050	.063	100 - 160	1.25	1.60
6.30 & over - To find fixed dimensional tolerances multiply by 0.8%.			160 & over - To find fixed dimensional tolerances multiply by 0.8%.		

METRIC

Drawing Designation "A4" tolerances apply to products where dimensional control is non-critical and secondary to cost.

Measurement of Dimensions

Conditioning of Parts: Measurements of dimensions shall be made on parts conditioned at least 24 hours after the molding operation. Measurements shall be completed within 60 days after shipment or before the part is put into use, whichever is the shorter time. Care shall be taken to insure that the parts are not subjected to adverse storage conditions.

In the case of referee measurement, particularly on Drawing Designation "A1" tolerances or for materials known to be sensitive to variations in temperature or relative humidity, the parts in question should be conditioned for a minimum of 24 hours at 23° ± 2° C (73.4° ± 3.6° F) and at 50% ± 5% relative humidity.

Methods of Measurement: Depending upon the characteristics of the dimension to be measured, one or more of the following methods of measurements may be used.

(A) A dial micrometer with a plunger size and loading as agreed upon by the customer and the rubber manufacturer.

(B) A suitable optical measuring device.

(C) Fixed gauges appropriate to the dimensions being measured.

Under no circumstances should the part be distorted during measurement. On dimensions which are difficult to measure or which have unusually close tolerances, the exact method of measurement should be agreed upon in advance by the rubber manufacturer and the customer.

Relative Dimensions

General Information: Relative dimensions such as concentricity, squareness, flatness, parallelism, or location of one or more inserts in the product are dimensions described in relation to some other dimension. Since it is impossible to foresee the many potential designs of all molded products in which relative dimensions will be specified, it is impractical to assign standard drawing tolerance designations to these dimensions. The design engineer should recognize that the more precise the requirement, the more expensive the product. He must allow the rubber manufacturer to use support pins, lugs, chaplet pins, or ledges in the mold to provide positive location and registration of the insert or inserts in the mold cavity. With this in mind, it is suggested that the design engineer discuss relative dimensional tolerances on all products directly with the rubber manufacturer.

Other factors do affect tolerances to some minor degree. Our attempt has been to acquaint the design engineer with background information on the major factors which result in the need for tolerances on molded rubber products.

Examples of Relative Dimensions: Several examples of relative dimensions the design engineer may be required to consider are shown:

(A) Concentricity

(B) Squareness

(C) Flatness

(D) Parallelism

In all cases the tolerances should be considered only as a very general guide.

CONCENTRICITY

Concentricity is the relationship of two or more circles or circular surfaces having a common center. It is designated as T.I.R. (total indicator reading) and is the total movement of the hand of an indicator set to record the amount that a surface varies from being concentric.

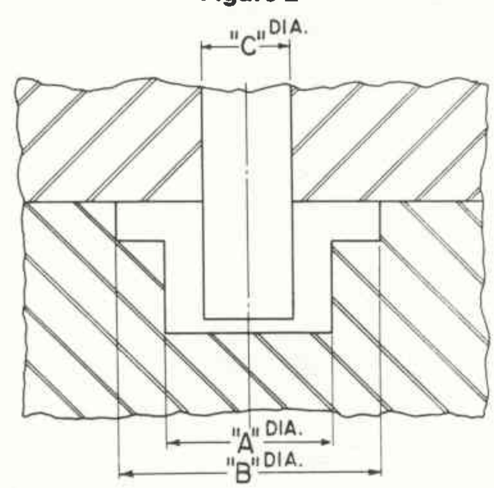
All diameters formed in the same mold plate will be concentric within .010 in. TIR (0.25 mm TIR).

Example:
In Fig. #2 diameter "A" will be concentric with diameter "B" within .010 in. TIR (0.25 mm TIR).

Other diameters will be concentric within 0.030 in. TIR (0.75 mm TIR).

Example:
In Fig. #2 diameter "A" or "B" will be concentric with diameter "C" within .030 in. TIR (0.75 mm TIR).

Figure 2

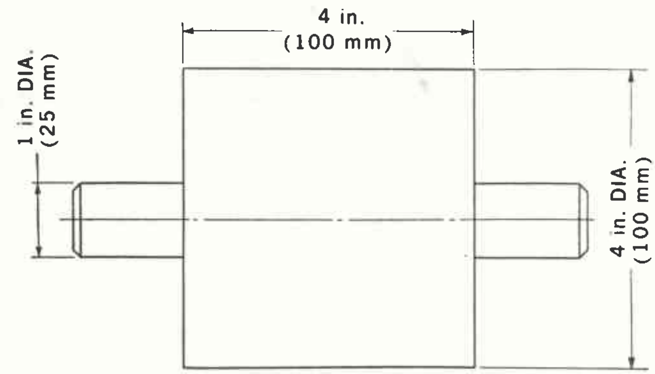


DIA. "B" NOT OVER 2 in. (50 mm).

Example:
Fig. #3 Outside surface will be concentric with shaft within .030 in. TIR (0.75 mm TIR) plus metal tolerance if unground.

Note: Parts may be ground to closer tolerances.

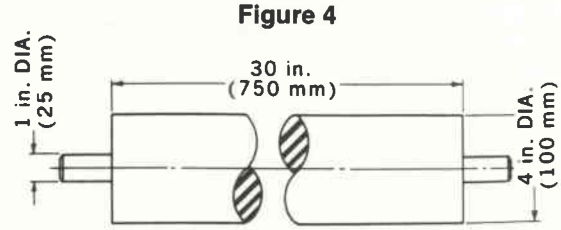
Figure 3



Example:
Fig. #4 Outside surface will be concentric with shaft within .085 in. TIR (2 mm TIR) plus metal tolerance if unground.

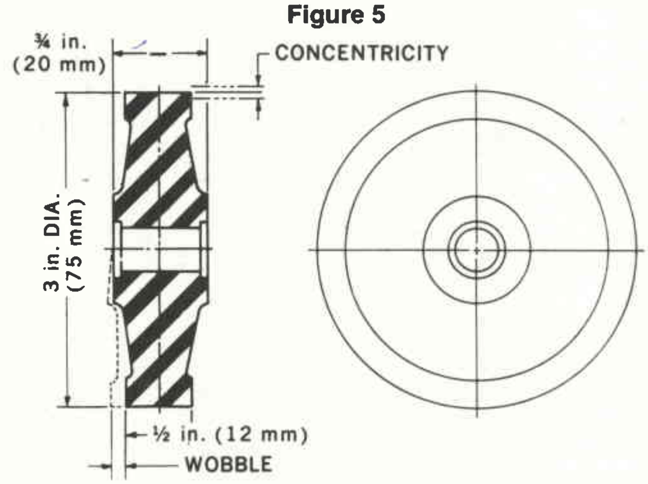
Note: Parts may also be ground to closer tolerances.

Figure 4



Example:
On products similar to that described in Fig. #5 having an outside diameter of 3 in. (75 mm) concentricity within .030 in. TIR (0.75 mm TIR) and wobble within .030 in. TIR (0.75 mm TIR) can be expected.

Figure 5



SQUARENESS

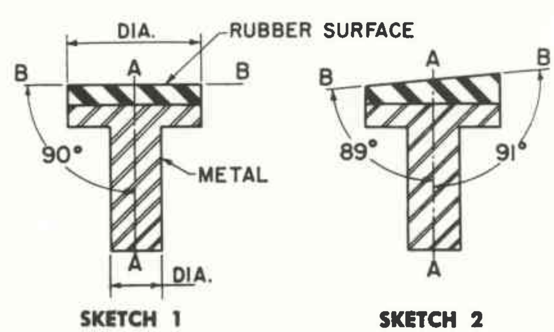
Squareness is the quality of being at an angle of 90° such as "surface must be square with axis". A tolerance of 2° should be allowed for rubber surfaces that are not ground.

Rubber Product with Metal Insert

Example:
Rubber-to-metal product in Sketch 1 Fig. #6. Rubber surface B-B is square with axis A-A as the angle is true 90°. Sketch 2 indicates the same example with 2° tolerances exaggerated.

Note: This type of product requires closer control than is usually normal with commercial products.

Figure 6



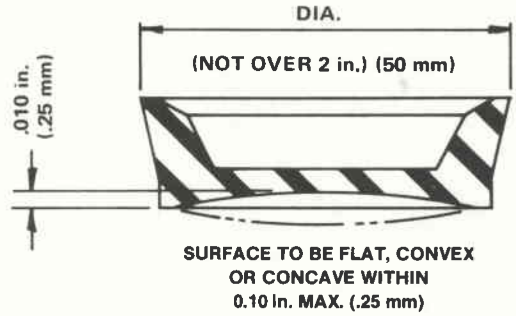
FLATNESS

Flatness of a surface on a part is the deviation from a true plane or straight edge.

Rubber Product (Unground). Molded Surfaces (unground) will be flat within .010 in. (0.25 mm).

Example:
Fig. #7 On a cup as illustrated, the bottom can be concaved or convexed by no more than .010 in. (0.25 mm).

Figure 7

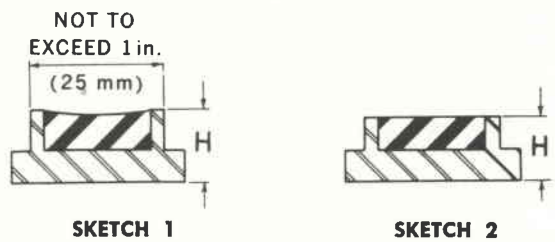


Rubber Product with Metal Insert. Surfaces that are ground after molding will be flat within .005 in. (0.12 mm). (Allowance must be made for removal of stock during grinding operation).

Example:
In Sketch 1 Fig. #8 after molding, deviation from the true plane can be held to .010 in. (0.25 mm).

Example:
In Sketch 2 Fig. #8 after grinding, deviation can be held to .005 in. (0.12 mm) but dimension "H" will necessarily be affected.

Figure 8



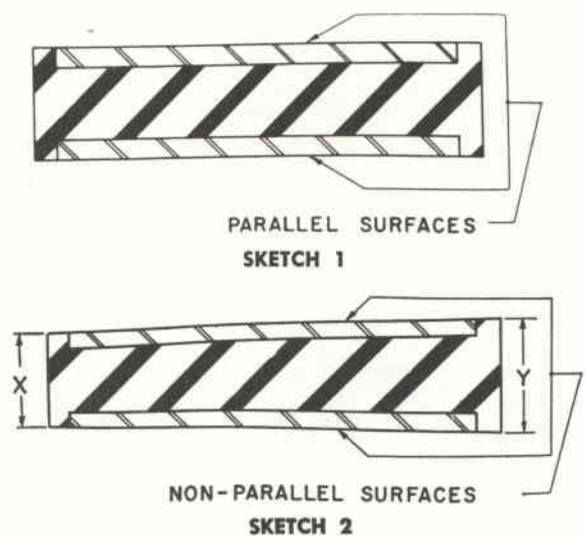
PARALLELISM

Parallelism is the relationship of surfaces in different planes. To be parallel the planes passing through the surfaces must be equidistant from each other at all points when measured at 90° to the planes.

Rubber Product with Metal Inserts.

Example:
In Sketch 1 Fig. #9 the plates of the sandwich mount are parallel. In Sketch 2 Fig. #9 they are not. On such a part approximately 8 in. (200 mm) square, parallelism to within .030 in. (0.75 mm) can be expected.

Figure 9



STANDARDS FOR FINISH AND APPEARANCE

Introduction

The purpose of this section is to list and discuss some of the factors that have an effect on the finish and appearance of molded products and to present standards covering four classes of finish.

FACTORS AFFECTING FINISH AND APPEARANCE

Machined Finish of Mold

The machined finish of the mold has considerable effect on the surface finish or appearance of a rubber product.

The best finish can be obtained from a highly polished steel mold, free from all tool marks or other imperfections. Naturally, this type of mold is quite expensive to construct and maintain and is not generally required unless surface finish is of paramount importance from either an appearance or functional standpoint. In addition, it may be desirable in some cases to chrome plate the mold in order to maintain the required surface finish under production conditions.

The commercial type mold is a machined steel mold made to conform to good machine shop practice. Machine tool marks will not ordinarily be polished out of this type mold. It should be noted that regardless of how highly the mold itself is polished, the appearance of the rubber surface will depend to a large extend upon the factors outlined in the following paragraphs.

Type of Rubber Material Used

The type of rubber material used can greatly affect the appearance of the rubber product. Some compounds lend themselves to a bright glossy surface while others may be dull as molded or become dulled very easily during handling or storage. Also, there are some rubber compounds to which antiozonants are added to impede attack from ozone. As these compounds age, the antiozonants "bleed out", giving the product a colored or waxy surface. This is a common practice and the product should not be considered imperfect or defective in any way. This or other specification requirements may make it impossible to produce a product with a glossy surface.

Mold Release Used

There are certain rubber compounds that can be removed from the mold with the use of little or no mold release lubricant, while others require the use of considerable quantity of mold release lubricant. The latter may have the appearance of being oily.

If the surface of the rubber product is to be bonded to other materials in its application or is to be painted, the designer should designate this on the drawing so that the manufacturer may use a mold release lubricant that will not impair adhesion quality.

Flash Removal Method

Some of the many methods used to remove flash from rubber parts may affect the appearance of the finished product. As an example, hand trimming will ordinarily have no effect, while tumbling may result in a dull surface.

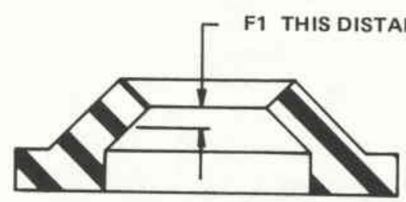
Method of Designation of Finish

The symbol "F" followed with an appropriate number selected from table 5 shall be used to designate the type of finish required.

An arc enclosing the actual area included by this designation and a leader to the finish number designates the type of finish desired. The use of a finish symbol on the surface does not preclude the possibility that other surfaces may require different finishes. However, the use of a standard notation is desirable wherever possible to eliminate the repetition of finish symbols and maintain simplicity. SEE FIG. #10.

Always permit "Commercial Finish" (F-3) whenever possible.

Figure 10



RMA A2-F3-T .003

Table 5
RMA DRAWING DESIGNATION FOR FINISH

Drawing Designation	
F 1	A smooth, polished and uniform finish completely free of tool marks, dents, nicks and scratches, as produced from a highly polished steel mold. In areas where F 1 is specified, the mold will be polished to a surface finish of 10 micro-inches (250 nm) or better.
F 2	A uniform finish as produced from a polished steel mold. In areas where F 2 is specified, the mold will be polished to a surface finish of 32 micro-inches (800 nm) or better but with very small tool marks not polished out.
F 3	Surfaces of the mold will conform to good machine shop practice and no micro-inch finish will be specified. This is "Commercial Finish".
F 4	Satin finish.

STANDARDS FOR FLASH

Introduction

It is the purpose of this section to list and discuss many of the factors that have an effect on the amount of flash, to describe the basic methods by which flash can be removed, and furnish the means by which the designer can designate on the product drawing the flash location and flash variation permissible.

Definition

(A) Flash.
Flash is excess rubber on a molded product. It results from cavity overflow and is common to most molding operations. Flash has two dimensions — Extension and Thickness.

(B) Flash Extension.
Flash extension is the film of rubber projecting from the part along the parting line of the mold.

(C) Flash Thickness.
Flash thickness is measured perpendicular to the mold parting line. Variations in flash thickness are normally included in closure tolerances.

General Information

A method for designating permissible flash extension and thickness on a molded product will result in better understanding between rubber manufacturer and consumer and benefit both. This method must permit the designation of a surface where no parting line is permissible. It must also designate areas where a parting line is permissible and define the amount of flash extension tolerable in such areas. The designer, without specific rubber processing knowledge, should be able to specify flash extension limits in any given area on his drawing. Use of RMA Drawing Designations provided in this section will provide this capability, however, the designer should not specify how flash is to be removed. He should specify the amount of flash extension which can be tolerated without impairing product function or appearance. A method designating areas permitting flash and describing flash extension tolerance will result in the following benefits:

(A) Avoid errors in mold design concerning parting line location.

(B) Uniformity in appearance and function of molded products supplied by more than one source.

(C) Simplification of inspection procedures.

(D) Reduce over-finishing or under-finishing products.

Molding techniques have been developed to produce "flashless" products. The mold parting line, depending on location on the product, is barely discernible with no measurable thickness or extension. Initial cost and maintenance of this tooling and equipment is high and very close manufacturing control is required.

In instances where flash extension is not a problem or where it is otherwise advantageous, parts are shipped as molded with no flash removal necessary.

Methods for removing flash from products with metal or other inserts are approximately the same as for non-inserted rubber products. Rubber flash adhering tightly to inserts is generally acceptable. If it must be removed, it is done by mechanical means such as wire brushing, abrasive belts or spot facing. If adhered rubber flash is not permissible, it should be so specified on the drawing.

Flash removal is an important cost factor in producing finished molded rubber products. Cost conscious designers will permit the widest possible latitude in flash thickness, flash extension, and in location of flash consistent with adequate function and appearance of the product.

FACTORS TO BE CONSIDERED IN SETTING STANDARDS ON FLASH

Flash Location

Parting lines (flash lines) must be located to facilitate part removal from the mold cavity after curing.

Flash Thickness

Flash thickness is determined in the molding operation and may vary with mold design, closing pressure, with weight and shape of preform, and type of compound used — and many lesser factors. Normal variations in flash thickness have been taken into account in the tables set up for closure tolerances, and this will receive no further consideration.

The designer should be aware that heavy or thick flash is frequently designed to facilitate removal of parts from the mold and to facilitate subsequent handling. In this regard the maximum thickness that can be tolerated without impairing the product function or appearance should be specified.

Flash Extension

There are many methods by which flash extension on rubber products can be removed. The particular method selected will be determined by the degree of flash extension permitted as well as by flash location, flash thickness, and other factors. Some of the more common methods of flash removal are as follows:

(A) Buffing
A moving abrasive surface material is applied to the rubber part to remove excess rubber by abrasive action.

(B) Die Trim
A cutting tool, shaped to the contour of the molded product at the parting line, is applied with a force perpendicular to the flash extension and against either a flat plate or a fitted shape. This creates a shearing or pinching action removing the excess flash. Die trim can be done with a hand or machine mounted die. Machine mounted dies are often used for multiple trimming of small uniformly shaped products from multi-cavity molds.

(C) Machine Trim
Flash is removed by passing the rubber part through machine mounted rotating or reciprocating cutting tools. These devices are customarily adapted to a particular product and may shear, saw, or skive the flash away.

STANDARDS FOR RUBBER-TO-METAL ADHESION

Introduction

The processes of adhering rubber to metal components are widespread techniques in the rubber industry. Generally the same considerations and procedures are applicable for rubber to rigid non-metallic components, but the adhesion values may be lower. Only the broad aspects of rubber-to-metal molding are covered here, and more precise information can be provided by the rubber manufacturer involved.

GENERAL INFORMATION

Application

Various adhesion levels can be obtained. For instance, to obtain adhesion on critical products, such as motor mountings, very close controls are usually required, both on metal and rubber preparation. With less critical products, such as some pedal pads and closures, which require only enough adhesion for assembly, close controls are not necessary.

The adhesion level is directly affected by types of metal, metal surface preparation, non-metallic inserts, compound variation, compound tensile strength, and type of elastomer.

Drawings should clearly state adhesion requirements and any other factors which can explain the degree of adhesion required and the method of testing. A clear understanding between customer and rubber manufacturer is essential.

Methods of Obtaining Adhesion

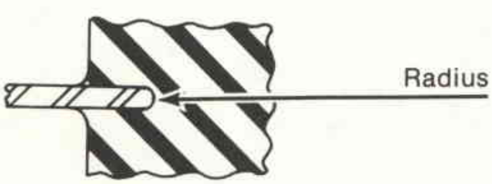
The method most commonly used to obtain adhesion between rubber and metallic or non-metallic components is the use of adhesive cements. Prior to the use of these special adhesives, the surface of the insert must be clean and free of contamination.

The inserts may be prepared by suitable methods such as degreasing, blasting, and/or a suitable chemical treatment. When any one of these preparatory processes is objectionable, it should be noted on the drawing. The rubber compound is then vulcanized to the prepared inserts to obtain the desired adhesion.

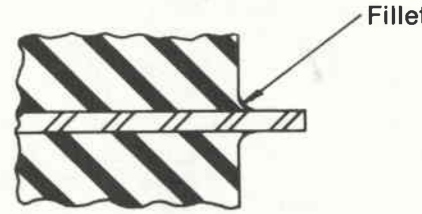
Design Factors and Limitations

a. Avoid localized stress raising irregularities.

b. Minimize edge effects. Break, coin, or otherwise eliminate sharp edges of all metallic members covered by the rubber.



Provide fillets in the rubber at junction line with inserts where possible.



Where fillets are not possible, extend the rubber beyond the edges of the inserts which would otherwise terminate line to line with the rubber.

c. Minimize surface roughness of metallic members in area of adhered rubber.

d. Avoid welding a molded rubber component to a machine or structure to prevent unnecessary heat deterioration. When welding is mandatory, design metallic member as a heat sink and provide for assembly techniques which will keep the adhered rubber area of the metallic member below 302° F (150° C).

Test Methods for Determining Adhesion Values

Adhesion testing is done in several ways, depending upon the application and the product design. The methods recognized for this testing are treated in full detail in ASTM Test Method D 429. These methods are:

Method A. Rubber adhered between two parallel metal plates.

Method B. Ninety degree stripping test, rubber adhered to one metal plate.

The above methods are used primarily for laboratory development and testing production parts. These methods may be modified and applied as described under RMA Production Test Methods section as follows.

RMA PRODUCTION TEST METHODS

Method A. Used where two metal surfaces, not necessarily parallel, can be separated until the specified adhesion value is obtained using the projected adhered area. The area to be considered should be the projected active adhered working area of the smallest metallic member, excluding fillets, overedge, and radii. Very irregular areas are to be given special consideration.

Method B. Used where the rubber can be stripped from the entire width of the part to obtain a specified adhesion value or where the rubber can be cut in 1 in. (25 mm) wide strips. Specimen rubber thickness shall not exceed 3/8 in. (approx. 10 mm). In rubber sections over 3/8 in. (approx. 10 mm), values should be negotiated between customer and supplier.

Acceptance Criteria

Looseness contiguous to the adhered areas at corners,

(D) Tumble Trim
There are two basic types of tumble trimming. Both utilize a rotating barrel or drum in which the heavier rubber sections strike the thinner and more fragile flash breaking it free. Dry tumbling at room temperature is most effective with the higher durometer "hard" compounds. The other type of tumbling utilizes carbon dioxide or other refrigerant to freeze the molded parts, thus making the compound more brittle so the flash will break more readily. Any tumbling operation will have an effect on surface finish.

(E) Mechanical Deflashing
Modern deflashing machines utilize an abrasive medium, tumbling, and a refrigerant for quick freezing. The time and temperature is closely controlled while the parts are agitated in an enclosed barrel. Refrigerant (usually carbon dioxide or nitrogen) is metered into the deflashing chamber while the parts are being impinged with a mechanically agitated abrasive medium. The flash, being thin, freezes first and is broken away by the abrasive medium and the tumbling action before the heavier rubber part itself has lost its resiliency. Some loss of surface finish may be expected and some of the abrasive medium may adhere to the molded parts.

(F) Pull Trim or Tear Trim
A very thin flash extension is molded immediately adjacent to the part and a thicker flash is molded adjacent to the thin flash but farther from the part. When the flash is pulled from the molded part, it separates at its thinnest point adjacent to the molded part. This method may result in a saw tooth or irregular appearance and it is limited to certain compounds and product designs.

(G) Hand Trim
Flash is removed by an expedient method using hand tools such as knives, scissors, razor blades or skiving knives.

Method of Designation of Flash

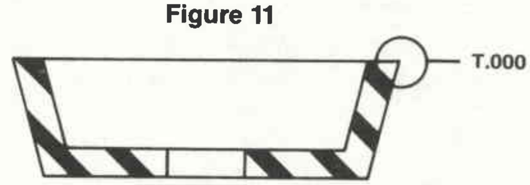
Extension
The symbol "T" with a notation in thousandths of an inch for the maximum extension shall be used. Example: T .032 (.032 in. maximum extension permitted.) IF METRIC DIMENSION THE DRAWING DESIGNATION WILL BE FOLLOWED BY mm INDICATING mm OF FLASH PERMITTED. EXAMPLE T .80mm

Thickness
The flash thickness may be specified following the extension limit if it is critical to the function of the part. Closure tolerances will apply as in tables 1, 2, 3, and 4 on page 5.

Location
An arc enclosing the actual area included by this designation and a leader to the trim symbol, designates the maximum allowable flash extension and thickness thus enclosed. If no flash can be tolerated in a given area, the symbol "T" .000 is used. SEE FIG. #11.

Standards
The designer may indicate on his drawing any amount of maximum flash extension permissible. However, as a matter of simplicity, a progression of flash extension Drawing Designations is suggested in Table 6. Only those areas requiring such a designation should be specified. The use of a standard note can frequently be used with no further notation. SEE FIG. #11.

Figure 11



RMA A1-F.2-T .016

Table 6
RMA DRAWING DESIGNATION FOR FLASH EXTENSION

Drawing Designation	
T. 000	(T. 00 mm) No flash permitted on area designated. (Standard notation regarding other surfaces must accompany this notation.)
T. 003	(T. 08 mm) This tolerance will normally require buffing, facing, grinding or a similar operation.
T. 016	(T. 40 mm) This tolerance will normally require precision die trimming, buffing or extremely accurate trimming.
T. 032	(T. 80 mm) This tolerance will normally necessitate die trimming, machine trimming, tumbling or hand trimming.
T. 063	(T1. 60 mm) This would be the normal tear trim tolerance.
T. 093	(T2. 35 mm) This tolerance will normally require die trim, tear trim, or hand trim of some type.
T. ∞	(T ∞) No flash limitation.

fillets, mold parting lines, and back-rinding will ordinarily be acceptable.

The adhesion strength is usually considered to be satisfactory if the failure causes permanent distortion of a metallic member.

If the deformation of the rubber section under test far exceeds the functional service requirements, this factor should be taken into consideration when establishing a reasonable adhesion value.

It is recognized that conditions for adhesion will exist where a quantitative value cannot be obtained. In these instances, it is customary to pull the rubber from the metallic member and examine the nature of the failure. The acceptable degree of adhesion must be agreed upon between the customer and the rubber manufacturer. Customer's test methods and fixtures should be identical with those of the rubber manufacturer and correlation procedures established.

METHODS OF DESIGNATING ADHESION VALUES

The design engineer when writing specifications, should use a designation to obtain suitable adhesion for the purpose intended.

Methods of testing, such as tension pull or shear pull (RMA Production Method "A") or 90 degree stripping (RMA Production Method "B") and the minimum destruction values, as well as the design of special testing fixtures should be specified on the drawings. ASTM D2000 — SAE J200 has two types of adhesion designations for adhesion of vulcanized rubber to metal:

1. Adhesion by vulcanization, designated by K11 or K21.
2. Adhesion by the use of cements or adhesives after vulcanization, designated by K31.

This section is concerned only with K11 and K21.

Table 7
RMA DRAWING DESIGNATION FOR RUBBER-TO-METAL ADHESION CLASSIFICATION

Drawing Designation	
B1 (Specify method and grade from Table 8.)	Production 100% tested to 70% of the minimum destruction values as noted in Table 8, Method A only. In addition, sample parts tested to destruction must exceed the minimum destruction values as noted in Table 8 (Specify Method A or Method B and Grade.)
B2 (Specify method and grade from Table 8.)	Sample parts tested to destruction must exceed the minimum destruction values as noted in Table 8.
B3	Rubber to be adhered to metal. This designation would ordinarily be used on products where adhesion is not critical to product function.
B4	Mechanical attachment only. Rubber is not adhered to metal.
B5	Products requiring special consideration.

As an illustration of the above drawing designation, see Example 4 in the Summary of RMA Drawing Designations on page 17.

Table 8
RMA DRAWING DESIGNATION FOR MINIMUM ADHESION DESTRUCTION VALUES

METHOD A

Drawing Designation	**USA Customary Units**		**S.I. Metric Units**
Grade 1	400 psi		2.8 MPa
Grade 2	250 psi	For rubber compounds over 1500 psi (10.5 MPa) tensile strength and 50 or greater hardness	1.75 MPa
	200 psi	For rubber compounds under 1500 psi (10.5 MPa) tensile strength or under 50 hardness	1.4 MPa
Grade 3	50 psi		0.35 MPa

METHOD B

Drawing Designation	USA Customary Units		S.I. Metric Units
Grade 1	90 lbs./in. width		16 kN/m width
Grade 2	50 lbs./in. width	For rubber compounds over 1500 psi (10.5 MPa) tensile strength and 50 or greater hardness	9 kN/m width
	40 lbs./in. width	For rubber compounds under 1500 psi (10.5 MPa) tensile strength or under 50 hardness	7kN/m width
Grade 3	15 lbs./in. width		2.7 kN/m width

As an illustration of the above drawing designation, see Example 4 in the Summary of RMA Drawing Designations on page 17.

Table 8 is applicable only to RMA B1 and B2 levels shown in Table 7.

All grades of adhesion cannot be obtained with all compound classifications.

Grade 2 is similar to ASTM-SAE K11 and K21.

STANDARDS FOR STATIC AND DYNAMIC LOAD DEFLECTION CHARACTERISTICS

Introduction

Primarily, rubber is used in place of metallic, ceramic, and other rigid materials because it will provide a greater deflection for a given force than these other materials. Most uses of rubber are based upon this characteristic.

In many uses of rubber, stiffness variation is not critical to the rubber product function and in such cases the Shore A durometer hardness specification is sufficient.

Rubber is used as an engineering material in resilient mountings, vibration isolators, dampers, impact pads and many similar applications. Where static or dynamic stiffness characteristics become critical to the function of the product, appropriate test specifications must be established.

METHODS AND CONSIDERATIONS

Static Methods

When a static load-deflection specification is established for a product, in addition to a hardness requirement, the load-deflection specification shall supercede the hardness, should be stated on the product drawing, and agreed upon between the customer and the rubber manufacturer. A static test is only "static" in that the load application comes to rest before the measurement is taken or the rate of deflection does not normally exceed 2 in./min. (0.8 mm/s). Such a test usually places the rubber in shear or compression. There are several ways of specifying static load-deflection characteristics:

a. Specify spring rate in load per unit deflection, e.g., lb./in. (N/m) or torque per radian, e.g., lb. in./rad. (N.m/rad.).

b. Specify a load to deflect the product within a specified deflection range.

c. Specify a deflection resulting in a load within a specified load range.

Dynamic Methods

Applications where rubber is used as vibration isolators are dependent upon the behavior of the rubber under dynamic operating conditions.

Rubber is stiffer dynamically than in a static mode; and, since the static to dynamic stiffness ratio varies with individual compounds, it may be advisable to specify the dynamic characteristics of the rubber for such applications.

When dynamic stiffness or spring rate is specified, and is critical to the rubber product performance, the complete conditions and methods of measurement must be established between customer and rubber manufacturer.

There are several methods of dynamic testing:

a. Steady State Resonance

b. Free Decay Resonance

c. Steady State Non-Resonant

d. Rebound Evaluation

FACTORS AFFECTING STATIC AND DYNAMIC LOAD DEFLECTION CHARACTERISTICS

Age

The aging of rubber compounds over a period of time is a complex process. The normal net effect of aging is an increase in modulus or stiffness. The magnitude of this change is dependent upon the specific material involved and the environmental conditions.

Short term age, in the sense of the minimum number of hours which should elapse between molding and evaluation, is also a significant factor. Depending upon the nature of the product, the minimum period will vary from 24 hours to 168 hours.

Dynamic History

The load-deflection characteristics of a rubber product are affected by the work history of that specific product. The initial loading cycle on a new part, or a part that has been in a static state for a period of time, indicates a stiffer load-deflection characteristic than do subsequent cycles. In static testing this effect becomes stabilized and the load-deflection characteristics normally become repeatable after two to four conditioning cycles.

In dynamic testing, the conditioning period is normally selected as the time required to obtain reproducible results.

Temperature

Temperature has an effect on spring rate — the higher the temperature the lower the spring rate, and the lower the temperature the higher the spring rate of a rubber product not under continuous tension.

Test Conditions

The following details must be defined by the product drawing, or referenced specification, to insure relevant and consistent product performance evaluation:

a. Mode of Test

1. Tension, Shear or Compression. A schematic diagram depicting product orientation is highly desirable. The spring rate in the compression mode is always higher than the spring rate in the shear mode.
2. Static or Dynamic

   The dynamic spring rate is always higher than the static spring rate.

b. Test Level and Control Mode

1. Static testing load level or level of deformation, together with the appropriate limits on deflection or limits of loading in response to deformation, shall be stated.
2. Dynamic load levels shall be identified by a plus (+) value for downward forces and a negative (−) value for upward forces. Dynamic tests utilizing deformation control shall be specified by double amplitude (total amplitude) values.

c. The amount and direction of preload, if required.

d. The linear or angular rate of loading or cyclic frequency.

e. The nature and number, or duration, of conditioning cycles required prior to the test cycle or test period.

f. The ambient test temperature and the period of time the product is held at test temperature prior to evaluation.

g. When the requirements are stated as "Spring Rate" the location on the load-deflection chart at which the tangent is drawn, or the load levels between which an average is taken, must be indicated.

METHODS OF DESIGNATING STATIC & DYNAMIC TOLERANCES

When applicable, the design engineer must specify load-deflection, spring rate, method of test and load-deflection tolerances. Table 9 presents standards for the three drawing designations for load-deflection tolerances.

If damping characteristics are required as a part of a dynamic specification, commercial tolerances would be ± 25% on parts up through 65 durometer hardness and ± 30% for above 65 durometer hardness.

Table 9

RMA DRAWING DESIGNATIONS FOR LOAD DEFLECTION TOLERANCE

Drawing Designation	Durometer Hardness	Tolerance Range Rubber Wall Thickness 0.25 in. (6 mm) or over	Tolerance Range Rubber Wall Thickness under 0.25 in. (6 mm)	
D1	65 Durometer Hardness (Shore A) or below	± 10%	±15%	Very high precision. This close tolerance should only be requested in unusual circumstances.
	Above 65 Durometer Hardness (Shore A)	± 15%	± 20%	
D2	65 Durometer Hardness (Shore A) or below	± 11% to ± 14%	± 16% to ± 20%	Precision
	Above 65 Durometer Hardness (Shore A)	± 16% to ± 19%	± 21% to ± 26%	
D3	65 Durometer Hardness (Shore A) or below	± 15%	± 20%	Commercial
	Above 65 Durometer Hardness (Shore A)	± 20%	± 25%	

SUMMARY AND EXAMPLES OF RMA DRAWING DESIGNATIONS MOLDED RUBBER PRODUCTS

DRAWING DESIGNATIONS

The design engineer should select and designate on the drawing a separate RMA designation for each characteristic noted. Relative dimensions, bonding, spring rate or load-deflection characteristic to be used only when applicable. (See examples below.) If no designation is specified, the rubber manufacturer will assume that commercial tolerances apply.

Example 1:
Commercial tolerances; commercial finish; flash extension .032 in (.80 mm) would be designated on the drawing as follows: RMA A3 — F3 — T.032 (T.80 mm).

Example 2:
Precision tolerances; commercial finish; flash extension .032 in (.80 mm) and special agreement on bonding to metal would be designated on the drawing as follows: RMA A2 — F3 — T.032 (T.80 mm) — B5.

Example 3:
Non-critical tolerances; commercial finish; flash extension .032 in (.80 mm) would be designated on the drawing as follows: RMA A4 — F3 — T.032 (T.80 mm).

Example 4:
Precision tolerances; good finish; flash very close; (bond samples tested to 90 lb/in. (16kN/m) width to destruction) would be designated on the drawing as follows: RMA A2 — F2— T.016 (T.40 mm) — B2 Grade 1 Method B.

Figure 12

Tolerances (Tables 1-4)	Relative Dimensions	Finish (Table 5)	Flash Extension (Table 6) inches	mm	Bonding (Specify Grade and Method on B1 & B2 Table 7 & 8)	Load-Deflection Characteristic (Specify only when needed Table 9)
A1	No designation, see text and/or your rubber supplier. Specify only when needed.	F1	T.000	T.00 mm	B1	D1
A2		F2	T.003	T.08 mm	B2	D2
A3		F3	T.016	T.40 mm	B3	D3
A4		F4	T.032	T.80 mm	B4	—
—		—	T.063	T1.60 mm	B5	—
—		—	T.093	T2.35 mm	—	—
—		—	T ∞	T ∞	—	—

STANDARDS FOR PACKAGING

When a rubber part is packaged, it is for the sole purpose of transporation from the supplier to the user. Packaging usually causes some distortion of the rubber part which, if used in a reasonable length of time, does not permanently affect the part. However, when rubber parts are held in a distorted position for a prolonged period of time, permanent set may cause permanent distortion and result in unusable parts. Any product on which distortion may make the part unusable should be specified and packaged by such methods as will prevent distortion. However, such methods are sometimes costly and should not be specified unless absolutely necessary. When distortion is a problem, the product should be removed from the container when received and stored on shelves or in a manner to preserve usability. Packaging is a complex area and should be given serious consideration. Table 10 at right is to be considered only as a guide. Special packaging problems should be considered between purchaser and supplier.

Table 10

PACKAGING

Drawing Designation	
P1	This class of product will be packaged to eliminate all possible distortion during transportation and storage. This may require special boxes, cartons, forms, cores, inner liners, or other special methods.
P2	This class of product will be packaged in corrugated containers or boxes. The quantity of the product packaged per container will be held to an amount which will not crush the lower layers from its own weight, but no forms, cores, inner liners, etc., are necessary.
P3	This class of product will be packaged in corrugated paper containers, boxes, crates, burlap bags or bundles, or on skids and pallets. This is the most economical method of packaging but may also produce the greatest distortion in the product.

Chapter 2

EXTRUDED RUBBER PRODUCTS

PURPOSE AND SCOPE

The purpose of this section is to outline in usable and easily understood form the methods used in the manufacture of a dense extruded rubber product, the problems that can arise from these methods and how they affect the finished product. By presenting this side of the process to the user he will be more adequately prepared to convey to the rubber supplier his needs and requirements. He will also be better able to understand the limits and tolerances that can normally be expected of this type product.

It is also the purpose of this section to improve the relationship of supplier and user through the use of common and meaningful terms and symbols (RMA Designations). Through this better understanding and the proper use of RMA Designations by the user, the manufacturer should be better able to supply the needs of the user thereby giving him better economy and satisfaction.

PRINCIPLES OF EXTRUSION

An extruded rubber product differs from a molded rubber product in that the rubber is forced through a die of the desired cross-section under pressure from an extruder. The extruded product leaves the extruder in a soft pliable unvulcanized state. The extruded product normally must be vulcanized before it is usuable.

Unvulcanized rubber compound is fed into the extruder. The flutes of the revolving screw carry the rubber forward to the die, building up pressure and temperature as it advances toward the die. The rubber is forced through the die by this pressure and swells in varying amounts depending on the type and hardness of the compound. Due to the many variables such as temperature, pressure, etc., the extrusion varies in size as it leaves the die thus requiring plus or minus tolerances on the cross-section. During the vulcanization the extrusion will swell or shrink in the cross-section and length depending on the compound used. After vulcanization a length of extrusion has a tendency to be reduced in dimension more in the center of the length than the ends.

The extruded product is vulcanized either in a heated pressure vessel (static vulcanization) or by the continuous vulcanization process. A brief description of each follows:

STATIC VULCANIZATION

The extrusion is conveyed from the extrusion machine to a station where it is cut to varying lengths depending on the finished length and placed on a metal pan in a free state, that is, it is not contained in a cavity as in molding. The part is then vulcanized in a heated pressure vessel known as an autoclave. Generally the autoclave is heated by steam which is allowed to fill the autoclave, building up the required temperature, which then vulcanizes the rubber into its usable form. This is known as open steam vulcanizing. The pressure surrounding the extrusion during open steam curing minimizes porosity in the extrusion.

CONTINUOUS VULCANIZATION

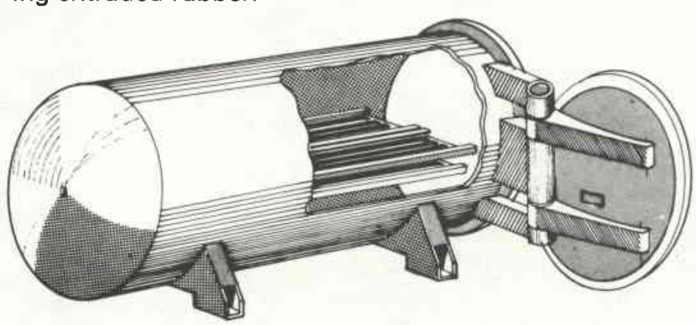
The extrudate is fed into the vulcanizing process directly from the extruder permitting the extrusion to be vulcanized in a continuous length. Several media are employed in the continuous vulcanization of rubber, all of which must be operated at elevated temperatures: air, molten salt, oils, fluidized beads, and microwave. Microwave is a method whereby the extrudate is subjected to high frequency electro magnetic waves which raises the temperature of the extrusion to near curing state, uniformly throughout. The rubber compounds processed by the continuous vulcanization process are special when compared to open steam vulcanized parts. The lack of pressure in most continuous vulcanization processes makes porosity in the extrusion difficult to control. For some rubber compounds the open steam cure process is most practical.

A great many variables are encountered in the extrusion process which make it necessary to require tolerances more liberal than molded parts. A design engineer should have a general knowledge of the extrusion process and its variables to enable him to design parts that can be extruded at reasonable cost.

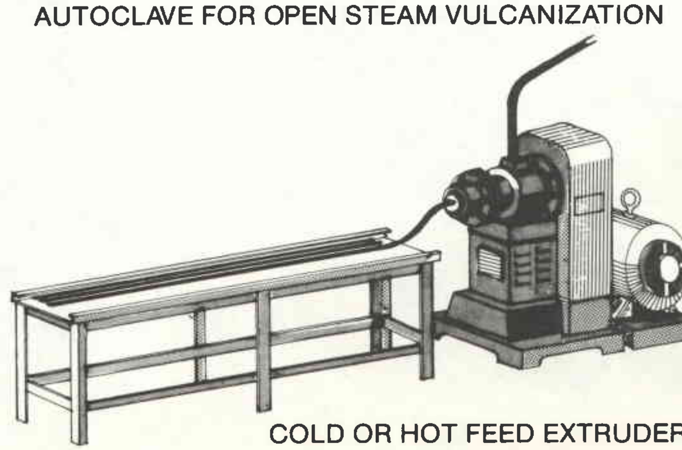
PROCESS ILLUSTRATIONS

RUBBER EXTRUDING SYSTEMS

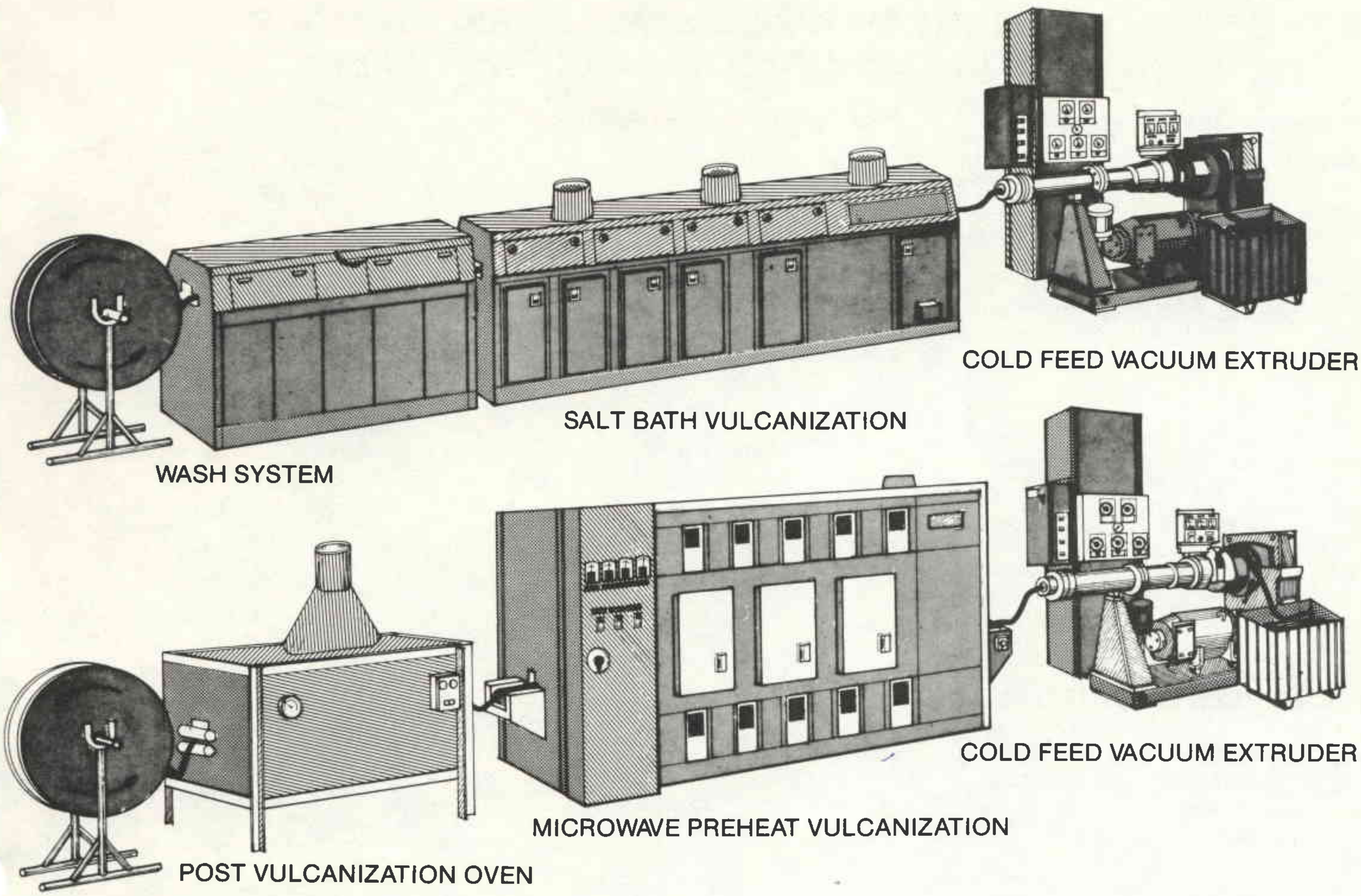
The systems shown below are a few variations of vulcanizing extruded rubber.



AUTOCLAVE FOR OPEN STEAM VULCANIZATION

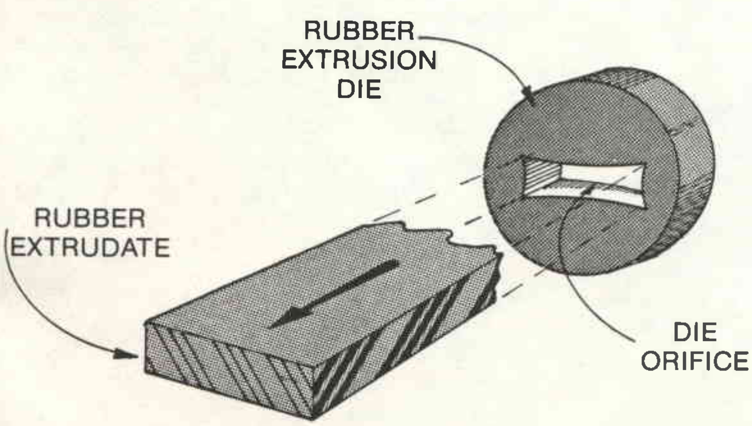


COLD OR HOT FEED EXTRUDER



EXTRUSION DIE

The extrusion die is a precise tool which is made by cutting an opening through a blank of steel; the opening is shaped to form the rubber into the desired cross-section as it is forced through the die by the pressure from the revolving screw of the extruder. Most rubber compounds swell and increase in dimension coming through the die orifice. Many rubber compounds are used and each has a different swell characteristic. Making a die is truly an art which is developed by years of experience. The die, by necessity, is made for a particular extruder and a particular compound.



The scope of this section presents to the user the tolerances and standards the rubber manufacturers are normally able to maintain relative to the following various areas of manufacture.

a) Limits on tolerance, due to hardness and quality effects, on extrusions.

b) Tolerance limits on cross-sectional dimensions; cut length dimensions; angle cuts; spliced lengths; ground surfaces; mandrel curing; and total indicator reading.

c) Standards for extruded finish; formed tubing; and packaging of extruded products.

d) Tolerances on cross-sectional dimensions, on silicone, polyacrylate, fluoroelastomers, and other polymers requiring post cures.

The applicability of this handbook to thermoplastic elastomers has not yet been determined.

SUMMARY OF RMA DRAWING DESIGNATIONS FOR EXTRUDED RUBBER PRODUCTS

Drawing Designations

In those cases where the design engineer can specify and accept one RMA Class on extruded products for the applicable qualifications on dimensional tolerances, ground surface, mandrel vulcanization, cut length, contour, forming, finish, T.I.R. and packaging, then the drawing need only carry the symbol for the acceptable class as RMA Class 1-2-3 or 4 as the case may be.

Normally, however, there will be exceptions to an RMA Class. By using the following chart, these exceptions can be noted.

Figure 13

RMA Class	Dimensional Tolerance Tables 13 and 14	Finish Table 15	Formed Tubing Table 16	Cut Length Tolerance Table 17	Angle Cut Tolerance Table 18	Spliced Length Tolerance Table 19
A	A	These tolerances where applicable are same as Class 1.				
1	A1	F1	H1	L1	AG1	S1
2	A2	F2	H2	L2	AG2	S2
3	A3	F3	H3	L3	AG3	S3
4		F4	H4			

RMA Class	Ground Surface Table 20	Mandrel Cured Table 21	T.I.R. Table 22	Silicone Dimensional Tolerance Table 23	Packaging Table 24
1	G1	M1	K1	Sil 1	P1
2	G2		K2	Sil 2	P2
3					P3
4					

Example 1:
If an RMA Class 3 product is acceptable except that it must be mandrel cured and have class 2 packaging, it would be shown on the drawing as follows: RMA Class 3 M1-P2.

Example 2:
If an RMA Class 2 product is acceptable but the wall thickness is critical and must be maintained to Class 1 tolerances, it would be shown on the drawing as follows: RMA Class 2 A1 with designating line or arrow to critical point, etc.

Lower numbered designations are tight tolerances, high numbered designations are more liberal tolerances.

Note: There is a relationship between hardness and the amount of tolerance which will be used. The lower the hardness the more tolerance necessary.

Because the hardness (or softness) and tensile strength of a compound to be extruded has much to do with the cross-sectional dimensional tolerances that can be maintained on extruded parts, standard tolerances must be divided into two schedules. The compounds are identified by ASTM D2000/SAE J200 designations as follows:

Non-oil resistant rubber (AA and BA types — natural rubber (NR); styrene-butadiene rubber (SBR); butyl rubber (IIR); butadiene rubber (BR); polyisoprene rubber (IR); ethylene propylene rubber, (EPDM); reclaim rubber and others.

Compounds made from medium volume swell (in petroleum hydrocarbons), polymers (BC and BE types) such as chloroprene rubber (CR) and compounds made from low volume swell polymers (BF and BG types) such as acrylonitrile rubber (NBR).

The first digit in the ASTM/SAE identification denotes hardness and the last two digits denote tensile strength (i.e., AA510 = 50 durometer, 1000 psi tensile strength).

These types are divided into groups for which Schedule 1 or Schedule 2 tolerances apply. No other ASTM/SAE designated compounds shall be applied to extruded parts for general commercial practice. Some of the other ASTM/SAE designated compounds not listed in Groups 1 or 2 and other compounds made from chlorosulfonated polyethlene (CSM), fluoroelastomers (FPM), polyacrylic (ACM and ANM), urethane (AU and EU) may be extruded but only with special handling and special tolerances. Silicone (SI), polyacrylic, fluoroelastomers and other post cured materials are covered in the section on Standards for Silicone, Polyacrylates, Fluoroelastomers and other Post Cured Materials page 32.

Compound Groupings

(For Reference Prior to Using Tables 13 through 22)

Table 11

Group 1 compounds — use schedule 1 tolerances

ASTM D 2000 SAE J 200	ASTM D 2000 SAE J 200	ASTM D 2000 SAE J 200
AA510 & BA510		
AA515 & BA515		
AA605 & BA605	BF605 & BG605	BC605 & BE605
AA610 & BA610	BF610 & BG610	BC610 & BE610
AA615 & BA615	BF615 & BG615	BC615 & BE615
AA620 & BA620	BF620 & BG620	BC620 & BE620
AA705 & BA705	BF705 & BG705	BC705 & BE705
AA710 & BA710	BF710 & BG710	BC710 & BE710
AA715 & BA715	BF715 & BG715	BC715 & BE715
AA720 & BA720	BF720 & BG720	BC720 & BE720
AA805 & BA805	BF805 & BG805	BC805 & BE805
AA810 & BA810	BF810 & BG810	BC810 & BE810
AA815 & BA815	BF815 & BG815	BC815 & BE815
AA820 & BA820	BF820 & BG820	BC820 & BE820
AA905 & BA905	BF905 & BG905	BC905 & BE905
AA910 & BA910	BF910 & BG910	BC910 & BE910
AA915 & BA915	BF915 & BG915	BC915 & BE915

Table 12

Group 2 compounds — use schedule 2 tolerances

ASTM D 2000 SAE J 200	ASTM D 2000 SAE J 200	ASTM D 2000 SAE J 200
		BC405 & BE405
AA410 & BA410	BF410 & BG410	BC410 & BE410
AA415 & BA415		
AA505 & BA505	BF505 & BG505	BC505 & BE505
	BF510 & BG510	BC510 & BE510
	BF515 & BG515	BC515 & BE515
AA520 & BA520		
AA525 & BA525		
AA625 & BA625		
AA725 & BA725		
AA825 & BA825		

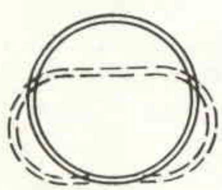
STANDARDS FOR CROSS SECTIONAL TOLERANCES

The following illustrations should be taken into consideration when designing rubber parts and when describing what is needed and expected from the manufacturer.

Extrusion Contour (Shape) Variation

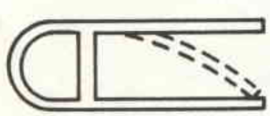
Contour designates the degree of rigidity and conformity to the cross sectional drawing. During vulcanization the tendency of the extrusion is to sag and flatten. The degree of change in shape is largely dependent upon the hardness or softness of the compound, the tensile strength or quality of the compound, the thickness or thinness of the cross sectional wall, the inner openings of the extrusion and the rate of vulcanization. This tendency to distort during vulcanization can best be eliminated by the use of forms or mandrels which generally add to the cost of manufacture. This cost can sometimes be eliminated if contour conformity is not necessary to the finished extrusion. The degree of allowable collapse or sag in a cross-section should be indicated on the blueprint as shown in illustrations below.

Figure 14



Tube may collapse as indicated by dotted line

Figure 15



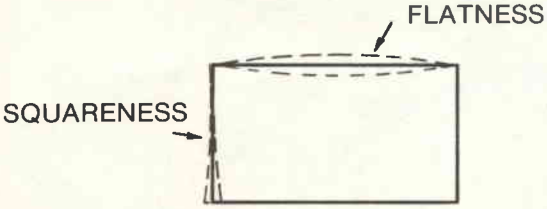
Lip may collapse as indicated by dotted line.

Figure 16

Squareness & Flatness of Rectangular Cross Sections

Tolerances for squareness and flatness of extruded sections are not included in these tables. Due to the difficulty of establishing meaningful limits to satisfy the wide area of needs, purchaser and manufacturer should discuss and agree on these limits.

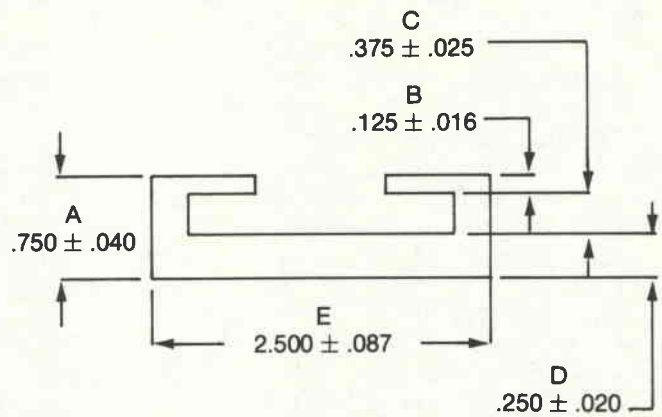
Illustration is for enlightenment only.



Cross Sectional Dimension Illustration.

Figure 17

Tolerances for illustration are taken from Schedule 1 Class 2 Table 13, page 23.

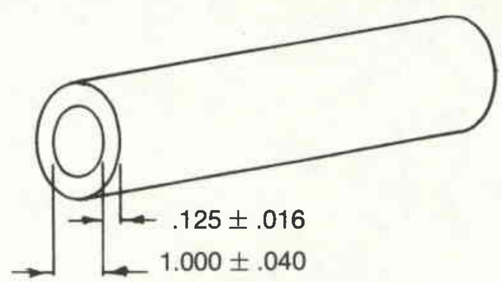


Dimension "C" in above illustration is affected by shape variation.

Figure 18

I.D. — O.D. Tube Tolerances

Tolerances should be established on the I.D. (or O.D.) and wall thickness only. To include a tolerance on both I.D. and O.D. generally conflicts with the other tolerances.



Tubing Tolerancing

Tolerances for I.D.-O.D. tubing are found in tables 13 & 14, page 23.

STANDARDS FOR CROSS SECTIONAL TOLERANCE TABLES

Tolerances for outside (O.D.) diameters, inside (I.D.) diameters, wall thickness, width, height and general cross sectional dimensions or extrusions. See Figures 17 and 18, Page 22.

Table 13

Schedule 1
Cross Sectional Tolerances for Group 1 — Compounds Only

HIGH PRECISION
RMA — CLASS A — DWG DESIGNATION A

Dimension (Inches)	Tolerance	Dimension (Inches)	Dimension (Millimeters)	Tolerance
Above—incl.		(Fractions)	Above-incl.	
0.00-0.10*	± .008	(0-3/32)	0.0- 2.5*	± 0.20
0.10-0.16	0.010	(3/32-5/32)	2.5- 4.0	0.25
0.16-0.25	0.013	(5/32-1/4)	4.0- 6.3	0.32
0.25-0.40	0.016	(1/4-13/32)	6.3-10.0	0.40
0.40-0.63	0.020	(13/32-5/8)	10.0-16.0	0.50
0.63-1.00	0.025	(5/8-1)	16.0-25.0	0.63
Use ± 2-1/4% for dimensions over 1.00 inch.				
PRECISION RMA — CLASS 1 — DWG DESIGNATION A1				
0.00-0.10*	± .010	(0-3/32)	0.0- 2.5*	± 0.25
0.10-0.16	0.013	(3/32-5/32)	2.5- 4.0	0.32
0.16-0.25	0.016	(5/32-1/4)	4.0- 6.3	0.40
0.25-0.40	0.020	(1/4-13/32)	6.3-10.0	0.50
0.40-0.63	0.025	(13/32-5/8)	10.0-16.0	0.63
0.63-1.00	0.032	(5/8-1)	16.0-25.0	0.80
Use ± 2-3/4% for dimensions over 1.00 inch.				
COMMERCIAL RMA — CLASS 2 — DWG DESIGNATION A2				
0.00-0.10*	± .013	(0-3/32)	0.0- 2.5*	± 0.32
0.10-0.16	0.016	(3/32-5/32)	2.5- 4.0	0.40
0.16-0.25	0.020	(5/32-1/4)	4.0- 6.3	0.50
0.25-0.40	0.025	(1/4-13/32)	6.3-10.0	0.63
0.40-0.63	0.032	(13/32-5/8)	10.0-16.0	0.80
0.63-1.00	0.040	(5/8-1)	16.0-25.0	1.00
Use ± 3-1/2% for dimensions over 1.00 inch.				
NON CRITICAL RMA — CLASS 3 — DWG DESIGNATION A3				
0.00-0.10*	± .016	(0-3/32)	0.0- 2.5*	± 0.40
0.10-0.16	0.020	(3/32-5/32)	2.5- 4.0	0.50
0.16-0.25	0.025	(5/32-1/4)	4.0- 6.3	0.63
0.25-0.40	0.032	(1/4-13/32)	6.3-10.0	0.80
0.40-0.63	0.040	(13/32-5/8)	10.0-16.0	1.00
0.63-1.00	0.050	(5/8-1)	16.0-25.0	1.25
Use ± 4-1/2% for dimensions over 1.00 inch.				

Table 14

Schedule 2
Cross Section Tolerances for Group 2 — Compounds Only

HIGH PRECISION
RMA — CLASS A — DWG DESIGNATION A

Dimension (Inches)	Tolerance	Dimension (Inches)	Dimension (Millimeters)	Tolerance
Above—incl.		(Fractions)	Above-incl.	
0.00-0.10*	± .010	(0-3/32)	0.0- 2.5*	± 0.25
0.10-0.16	0.013	(3/32-5/32)	2.5- 4.0	0.32
0.16-0.25	0.016	(5/32-1/4)	4.0- 6.3	0.40
0.25-0.40	0.020	(1/4-13/32)	6.3-10.0	0.50
0.40-0.63	0.025	(13/32-5/8)	10.0-16.0	0.63
0.63-1.00	0.032	(5/8-1)	16.0-25.0	0.80
Use ± 2-3/4% for dimensions over 1.00 inch.				
PRECISION RMA — CLASS 1 — DWG DESIGNATION A1				
0.00-0.10*	± .013	(0-3/32)	0.0- 2.5*	± 0.32
0.10-0.16	0.016	(3/32-5/32)	2.5- 4.0	0.40
0.16-0.25	0.020	(5/32-1/4)	4.0- 6.3	0.50
0.25-0.40	0.025	(1/4-13/32)	6.3-10.0	0.63
0.40-0.63	0.030	(13/32-5/8)	10.0-16.0	0.80
0.63-1.00	0.040	(5/8-1)	16.0-25.0	1.00
Use ± 3-1/2% for dimensions over 1.00 inch.				
COMMERCIAL RMA — CLASS 2 — DWG DESIGNATION A2				
0.00-0.10*	± .016	(0-3/32)	0.0- 2.5*	± 0.40
0.10-0.16	0.020	(3/32-5/32)	2.5- 4.0	0.50
0.16-0.25	0.025	(5/32-1/4)	4.0- 6.3	0.63
0.25-0.40	0.030	(1/4-13/32)	6.3-10.0	0.80
0.40-0.63	0.040	(13/32-5/8)	10.0-16.0	1.00
0.63-1.00	0.050	(5/8-1)	16.0-25.0	1.25
Use ± 4-1/2% for dimensions over 1.00 inch.				
NON CRITICAL RMA — CLASS 3 — DWG DESIGNATION A3				
0.00-0.10*	± .020	(0-3/32)	0.0- 2.5*	± 0.50
0.10-0.16	0.025	(3/32-5/32)	2.5- 4.0	0.63
0.16-0.25	0.030	(5/32-1/4)	4.0- 6.3	0.30
0.25-0.40	0.040	(1/4-13/32)	6.3-10.0	1.00
0.40-0.63	0.050	(13/32-5/8)	10.0-16.0	1.25
0.63-1.00	0.063	(5/8-1)	16.0-25.0	1.60
Use ± 5-1/2% for dimensions over 1.00 inch.				

Note: There is a relationship between hardness and the amount of tolerance which will be used. The lower the hardness the more tolerance necessary.

*General cross sectional dimensions below 0.040" (1 mm) are impractical.

STANDARDS FOR EXTRUDED FINISH AND APPEARANCE

In the process of producing extruded parts, it is necessary to use various lubricants, release agents, dusting agents, and other solutions. It may be necessary to remove these materials from the extrusion after vulcanization because of an appearance requirement. The cost of cleaning may be eliminated from those products which are concealed or do not hinder assembly. The purchaser's intent and desire in this area should be conveyed to the rubber manufacturer by use of the proper RMA class of finish designation. Full consideration of finish requirements may result in considerable cost savings on the product.

Table 15

DRAWING DESIGNATION FOR EXTRUSION FINISH

RMA Class	Drawing Designation	
1	F1	Product shall have surface finish smooth, clean and free from any foreign matter.
2	F2	Product shall have surface finish cleaned of dust and foreign matter but slight streaks or spots acceptable.
3	F3	Product shall have loose dust and foreign matter removed but natural finish (not washed) acceptable.
4	F4	Product shall be acceptable with no cleaning necessary. Dust or solution deposits acceptable. Coarse or grainy surface acceptable.

STANDARDS FOR FORMED TUBING (FOR SPECIAL SHAPES)

The type of product discussed in this section is formed by forcing unvulcanized tubing over a mandrel or flexible core bent to the required radii or shape.

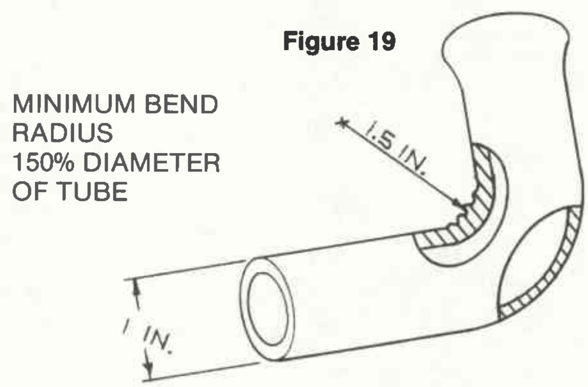
In forcing the unvulcanized tubing over the mandrel or flexible core and around a bend, the wall thickness will be stretched on the outside of the bend and compressed on the inside of the bend. If the bend or radius is too severe, folds or wrinkles will form on the inside of the bend and severe stretching will occur on the outside of the bend.

The minimum bending radius at which tubing may be formed will depend upon the outside diameter and wall thickness and should never be less than 150% of the outside diameter (O.D.).

If a small radius or a specific angle is required, the part should be molded. This is necessary because, in addition to folds and wrinkles on the inside of the radius, it may be impossible to force the tubing over the bend or to strip it from the mandrel during the manufacturing process.

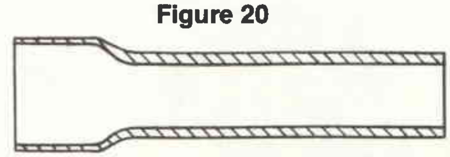
If a minimum wall thickness is specified, it will mean this minimum thickness must be furnished at the outside bend or stretched section, and depending on the severity of the bend or bends, it will require an oversize wall thickness on the rest of the tubing from 0.016 in. (0.40 mm) to 0.032 in. (0.80 mm) to insure the minimum thickness on the stretched area. If tubing is specified, it must be understood that, depending on the severity of the bend or bends, wall thickness will be from 0.016 in. (0.40 mm) to 0.032 in. (0.80 mm) undersize in the stretched areas.

Figure 19



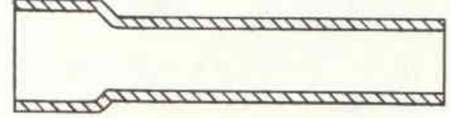
EXAMPLE OF RADIUS, STRAIGHT END, FLARED END, WRINKLES, BUCKLES AND WALL THICKNESS. MINIMUM BEND RADIUS.

Figure 20



EXAMPLE OF BLENDED CONTOUR

Figure 21



EXAMPLE OF DEFINITE CONTOUR

The leading end of the tubing will stretch and enlarge as it is forced over the mandrel or flexible core, according to the severity of the bend or bends and will not fully recover to original size during vulcanization. If both ends of the formed tubing must meet specification set forth for the original cross section, the product should either be molded or the lead end should be designed to fit a 0.063 in. (1.6 mm) oversize fixture. If the straight section adjacent to any sharp bend is to be shorter than 300% of the O.D. of the tube it must be understood that the tube must be made long enough to eliminate the flare and cut back to desired length after removal from mandrel. When forming tubing all bends and radii must be approximate, as natural spring-back of tubing formed under tension precludes the possibility of holding to an exact radius or shape. The tubing being flexible will adjust itself on assembly to compensate for these small variations. Measurement from beginning of bends or radii to other bends and radii are also approximate and subject to small variations for the same reasons.

Where expanded ends are required, the inside and outside of the tubing should blend from the regular cross section to the expanded cross section and not with a definite contour and radius as formed on a molded part. The walls of the enlarged section will be thinner than the regular section by 0.016 in. (0.40 mm) to 0.032 in. (0.80 mm), depending on the severity of enlargement. Expansion beyond 100% of I.D. of tubing is not practical. Any requirements beyond 100% must be molded.

Table 16

DRAWING DESIGNATION FOR FORMED TUBING

RMA Class	Drawing Designation	
1	H1	Product to be furnished to minimum wall thickness specified maintained throughout. Ends to be trimmed true and even.
2	H2	Product to be furnished to general cross section with stretched or thinner wall acceptable at bends or radii. Otherwise, same as Class 1.
3	H3	Product may be furnished partially out of round in straight or bent sections. Ends may not necessarily be straight and true. Minor flat spots permissible.
4	H4	Product may be furnished partially out of round in straight or bent sections. Flat spot and slight wrinkles or buckles permissible. Product may be cut to length in unvulcanized state. (Allow .500 in. (12.3 mm) for every 30 in. (750 mm) of length.) Special tolerance to be established between supplier and purchaser.

STANDARDS FOR CUT LENGTH TOLERANCES FOR NORMAL UNSPLICED EXTRUSIONS

Normal extrusions are classified as extrusions that generally require only extruding, vulcanizing and cutting to length. They are of various cross sectional designs and do not include lathe cut parts, formed tubing, or precision ground and cut parts. They are generally packed in a straight or coiled condition after being measured and cut to length.

The following tables are to be used to convey to the manufacturer the limits that are desired by the purchaser. It should be understood by the design engineers that due to the *stretch factor* in rubber, a period of conditioning at room temperature must be allowed before measurements for length are taken. Accurate measurement of long lengths is difficult because they stretch or compress easily. Where close tolerances are required on long lengths, a specific technique of measurement should be agreed upon between purchaser and manufacturer.

Three classes are given, each containing limit requirements of schedule 1 and schedule 2, as established from hardness and quality properties of Group 1 and Group 2 compounds.

Table 17

CUT LENGTH TOLERANCE TABLES FOR NORMAL UNSPLICED EXTRUSION

RMA Class	**1 (Precision)**		**2 (Commercial)**		**3 (Non-Critical)**	
Drawing Designation	**L1**		**L2**		**L3**	
Length (In Inches)	**Schedule 1**	**Schedule 2**	**Schedule 1**	**Schedule 2**	**Schedule 1**	**Schedule 2**
Above — Included						
0 — 4	± 0.040	± 0.050	± 0.063	± 0.080	± 0.100	± 0.125
4 — 6.3	0.050	0.063	0.080	0.100	0.125	0.160
6.3 — 10.0	0.063	0.080	0.100	0.125	0.160	0.200
10.0 — 16.0	0.080	0.100	0.125	0.160	0.200	0.250
16.0 — 25.0	0.100	0.125	0.160	0.200	0.250	0.315
25.0 — 40.0	0.125	0.160	0.200	0.250	0.315	0.400
40.0 — 63.0	0.160	0.200	0.250	0.315	0.400	0.500
63.0 — 100.0	0.200	0.250	0.315	0.400	0.500	0.630
100.0 — 160.0	0.250	0.315	0.400	0.500	0.630	0.800
Length (In Millimeters)						
Above — Included						
0 — 100	± 1.00	± 1.25	± 1.60	± 2.00	± 2.50	± 3.15
100 — 160	1.25	1.60	2.00	2.50	3.15	4.00
160 — 250	1.60	2.00	2.50	3.15	4.00	5.00
250 — 400	2.00	2.50	3.15	4.00	5.00	6.30
400 — 630	2.50	3.15	4.00	5.00	6.30	8.00
630 — 1000	3.15	4.00	5.00	6.30	8.00	10.00
1000 — 1600	4.00	5.00	6.30	8.00	10.00	12.50
1600 — 2500	5.00	6.30	8.00	10.00	12.50	16.00
2500 — 4000	6.30	8.00	10.00	12.50	16.00	20.00

METRIC

Note: Special consideration on tolerances will have to be given to both extremely soft and high tensile stocks.

STANDARDS FOR ANGLE CUT TOLERANCES FOR NORMAL EXTRUSIONS

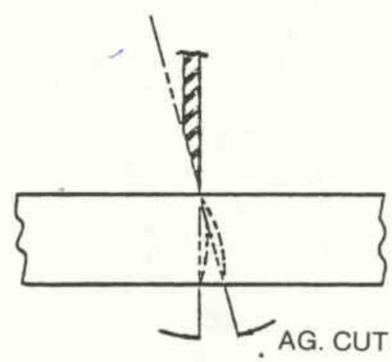
Many methods are employed to cut extruded sections to length; circular knife, rotating knife, guillotine, shear, saw and hand knife.

The angle and curve on cut face of extrusion will differ in degree depending upon the method used to cut the extrusion as well as the hardness of the compound, design or cross section and thickness of the extrusion.

Table 18

Angle (AG) Tolerances		
Drawing Designation		Cut (Max)
Precision	AG1	4°
Commercial	AG2	6°
Non Critical	AG3	10°

Figure 22



(The force of the knife upon the extrusion at the line of penetration deforms the extrusion resulting in a curved surface and an angle cut.)

DESIGN OF EXTRUDED ENDLESS SPLICES

When designing endless splices for extruded profiles several factors must be considered: durometer of compound, cut length, size of cross section and in the case of tubing, wall thickness.

Mold cavities are normally designed to the nominal dimension. If the extrudate cross section is at the top of the extruded tolerance mold pressure marks will be visible on the surface and more so with the use of lower durometer compounds. If the extrudate cross section is at the low end of the extruded tolerance the mold cavity would have to be shimmed in order to attain splicing pressure creating some surface marking. The longer the cut length the greater the difference in size at each end. (One end may be on high tolerance and the other end on low tolerance.) Generally, this gives the appearance of a step or mismatch. See Figure 28.

Tubing is subject to the same considerations but in addition, thin wall tubing may require internal support in order to achieve sufficient molding pressure. The type of insert used and whether or not it should be removed would have to be resolved between manufacturer and purchaser.

It is to the advantage of both customer and rubber manufacturer to discuss design and application of extruded endless splices. See Figure 29.

Figure 28

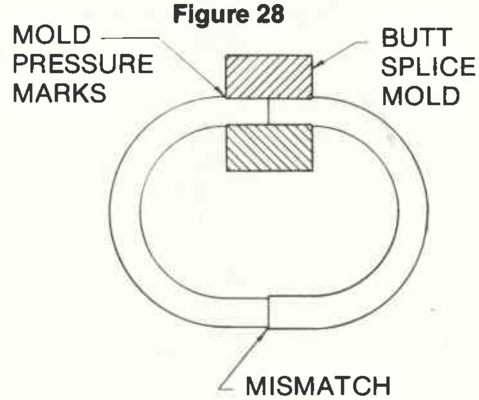
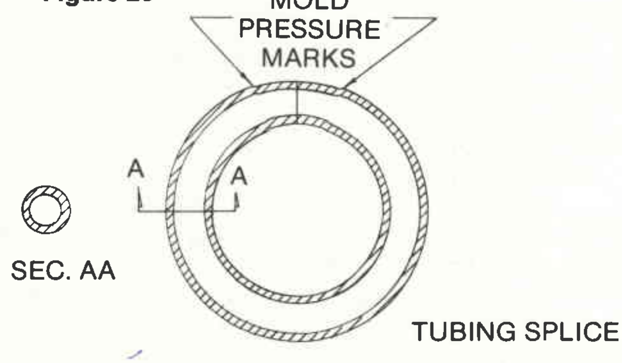


Figure 29



STANDARDS FOR GROUND SURFACE TOLERANCES

If it becomes necessary to hold the outside diameter of extruded mandrel cured tubing to closer tolerances than normal manufacturing methods will permit, this can be accomplished by surface grinding the part if the part has an inside diameter of 0.20 in. (5.0 mm) or more.

A drawing of this type of part should specify inside diameter or outside diameter, wall thickness, and outside finish. If ground finish is desired, it should be classified as one of the following: rough, smooth, or fine.

Table 20

GROUND SURFACE TOLERANCES

For Group 1 compounds only and for I.D. sizes .20 in. (5.0 mm) and larger.	
Drawing Designation G1 and G2	
Class	Tolerance
RMA Class 1	= .005 in. (.12 mm)
RMA Class 2	= .010 in. (.25 mm)
For Group 2 compounds only and for I.D. sizes .20 in. (5.0 mm) and larger.	
Drawing Designation G1 and G2	
Class	Tolerance
RMA Class 1	= .010 in. (.25 mm)
RMA Class 2	= .020 in. (.50 mm)

STANDARDS FOR TOLERANCES FOR MANDREL CURED PRODUCTS

When it becomes necessary to hold the tubing round and to close tolerances, a mandrel of the proper size must be inserted in the I.D. of the tubing before vulcanizing. This limits the length of the tubes. The shrinkage that occurs after removal from the mandrel causes the inside diameter to be less than the mandrel size or, in other words, tolerances are always minus with no plus. This means that tubes vulcanized on standard mandrels will have an I.D. less than standard and if the standard I.D. is necessary for the tubing, then special oversize mandrels are required. These specially ground oversize mandrels are expensive and many times can be avoided through an understanding of the problem and proper consideration of tolerances.

The designer should indicate what type of surface would be required on the O.D. of the tubing such as ground surface, cloth wrapped surface or as extruded. Any tube that has to have close tolerances on the O.D. generally will have a ground finish. A cloth wrap is used usually to help maintain a round I.D. and O.D. when the stock is soft and may sag in curing. The cloth wrapping of a tube (the tube is placed on a mandrel and wrapped tightly in cloth before vulcanizing and then removed after vulcanizing) leaves the imprint of the cloth weave in the rubber.

If type of surface is not indicated it would then be assumed that the surface is to be as extruded.

Table 21

MANDREL CURED TUBING TOLERANCES

GROUP 1 COMPOUNDS
RMA — CLASS 1 — DWG DESIGNATION M1

Dimension (inches)	Tolerances (inches)	Dimension (inches) Fractions	Dimension (millimeters)	Tolerances (millimeters)
Above-Incl.			Above-Incl.	
0-0.40	+0.000 -0.016	(0-3/8)	0-10	+0 -0.41
0.40-0.63	+0.000 -0.020	(3/8-5/8)	[illegible]	[illegible]
0.63-1.00	+0.000 -0.025	(5/8-1)	[illegible]	[illegible] 0.64
1.00-1.60	+0.000 -0.032	(1-1 5/8)	25-40	[illegible]
1.60-2.50	+0.000 -0.040	(1 5/8-2 1/2)	40-63	+0 -1.02
2.50-4.00	+0.000 -0.050	(2 1/2-4)	63-100	+0 -1.27

METRIC

GROUP 2 COMPOUNDS
RMA — CLASS 1 — DWG DESIGNATION M1

Dimension (inches)	Tolerances (inches)	Dimension (inches) Fractions	Dimension (millimeters)	Tolerances (millimeters)
Above-Incl.			Above-Incl.	
0-0.40	+0.000 -0.020	(0-3/8)	0-10	+0 -0.500
0.40-0.63	+0.000 -0.025	(3/8-5/8)	10-16	+0 -0.635
0.63-1.00	+0.000 -0.032	(5/8-1)	16-25	[illegible] 815
1.00-1.60	+0.000 -0.040	(1-1 5/8)	25-40	[illegible]
1.60-2.50	+0.000 -0.050	(1 5/8-2 1/2)	40-63	+0 -1.270
2.50-4.00	+0.000 -0.063	(2 1/2-4)	63-100	+0 -1.600

METRIC

RMA Class 2 and 3 products, page 23, would normally not require mandrel curing (see section on Contour page 22).

STANDARD FOR CONCENTRICITY OF MANDREL CURED AND GROUND EXTRUDED TUBING

CONCENTRICITY

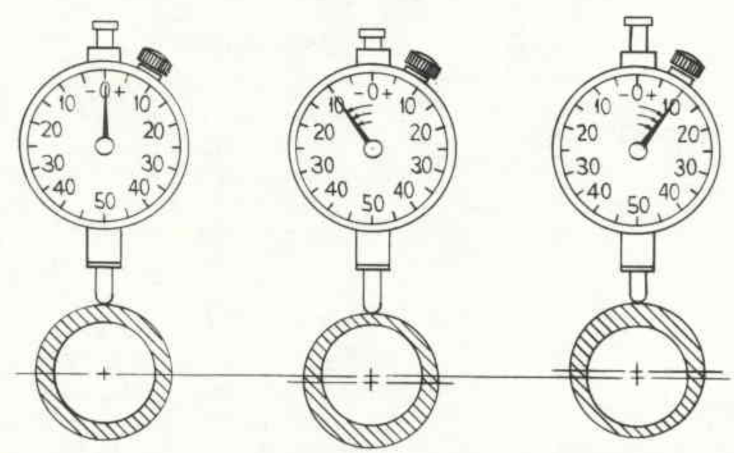
Concentricity is the relationship of two or more circles or circular surfaces having a common center. It is usually designated as T.I.R. (Total Indicator Reading) and is the total movement of the hand of an indicator set to record the amount that a surface varies from being concentric.

Table 22

T.I.R. TOLERANCES
FOR GROUP 1 AND GROUP 2 COMPOUNDS
INCHES

Outside Diameter Size In Inches	**K1 RMA Class 1 Mandrel Vulcanized And Ground**	**K2 RMA Class 2 Mandrel Vulcanized And Ground**
Above-Included		
— - 0.5	0.008	0.015
0.5 - 0.8	0.010	0.020
0.8 - 1.25	0.013	0.030
1.25 - 2.00	0.016	0.045
2.00 - 3.15	0.020	0.065
3.15 - over	0.025	0.090
MILLIMETERS		
Outside Diameter Size In Millimeters	**K1 RMA Class 1 Mandrel Vulcanized And Ground**	**K2 RMA Class 2 Mandrel Vulcanized And Ground**
Above-Included		
0 - .13	0.20	0.40
13 - 20	0.25	0.50
20 - 32	0.33	0.75
32 - 50	0.47	1.15
50 - .80	0.50	1.65
80 - over	0.64	2.30

EXAMPLE



CONCENTRIC NO INDICATOR MOVEMENT — NOT-CONCENTRIC INDICATOR MOVEMENT — NOT-CONCENTRIC INDICATOR MOVEMENT

When the above specimen is rotated 360° about the center of the inside circle with a dial indicator in contact with the outside circle, the total sweep of the indicator hand or difference to right and left of zero in above example is referred to as "Total Indicator Reading" or T.I.R. The T.I.R. in this example is 20 units.

STANDARDS FOR POSTCURED SILICONE, POLYACRYLATES, FLUOROELASTOMERS & OTHER POLYMERS

The processing and manufacturing of parts from Silicone, Polyacrylic and other polymers that require post vulcanizing requires special equipment and methods that necessitate wider tolerances. Separate areas of manufacturing to prevent contamination to or from these polymers are generally required. While new vulcanizing techniques enable more sophistication in extrusion cross sections, higher shrinkage and more difficult handling problems necessitate the inclusion of separate and more liberal tolerance tables for these polymers.

Table 23 applies to the tolerances on normal extruded cross sections.

Table 23

RMA CLASS 1 — DRAWING DESIGNATION SIL-A1				
Dimension (inches)	**Tolerance**	**Dimension (inches)**	**Dimension (millimeters)**	**Tolerance**
Above-Included			Above-Included	
0-0.10	± .006	(0-3/32)	0- 2.5	± 0.16
0.10-0.16	.010	(3/32-5/32)	2.5- 4.0	0.25
0.16-0.25	.016	(5/32-1/4)	4.0- 6.3	0.40
0.25-0.40	.025	(1/4-13/32)	6.3-10.0	0.63
0.40-0.63	.040	(13/32-5/8)	10.0-16.0	1.00
0.63-1.00	.063	(5/8-1)	16.0-25.0	1.60
1.00 & over — it is recommended that this tolerance be set after consultation with your fabricator.				

RMA CLASS 2 — DRAWING DESIGNATION SIL-A2				
Dimension (inches)	**Tolerance**	**Dimension (inches)**	**Dimension (millimeters)**	**Tolerance**
Above-Included			Above-Included	
0-0.10	± .008	(0-3/32)	0- 2.5	± 0.20
0.10-0.16	.013	(3/32-5/32)	2.5- 4.0	0.32
0.16-0.25	.020	(5/32-1/4)	4.0- 6.3	0.50
0.25-0.40	.032	(1/4-13/32)	6.3-10.0	0.80
0.40-0.63	.050	(13/32-5/8)	10.0-16.0	1.25
0.63-1.00	.080	(5/8-1)	16.0-25.0	2.00
1.00 & over — it is recommended that this tolerance be set after consultation with your fabricator.				

DISTORTION

Because rubber is a flexible material affected by temperature, distortion can occur when the part is stored or when it is packed for shipment. This distortion makes it difficult to measure the parts properly. Some of the distortion can be minimized by storing the part as unstressed as possible for 24 hours at room temperature.

ENVIRONMENTAL STORAGE CONDITIONS

Temperature

Rubber, like other materials, changes in dimension with changes in temperature. Compared to other materials the coefficient of expansion of rubber is high. To have agreement in the measurement of products that are critical or precise in dimension, it is necessary to specify a temperature at which the parts are to be measured and the time required to stabilize the part at that temperature.

Humidity

Some rubber materials absorb moisture. Hence the dimensions are affected by the amount of moisture in the product. For those products which have this property, additional tolerance must be provided in the dimensions. The effect may be minimized by stabilizing the product in an area of controlled humidity and temperature for a period not less than 24 hours.

STANDARDS FOR PACKAGING

When a rubber part is packaged, it is for the sole purpose of transportation from the supplier to the user. Packaging usually causes some distortion of the rubber part which, if used in a reasonable length of time, does not permanently affect the part. However, when rubber parts are held in a distorted position for a prolonged period of time, permanent set may cause permanent distortion and result in unusable parts. Any product on which distortion may make the part unusable should be specified and packaged by such methods as will prevent distortion. However, such methods are expensive and should not be specified unless absolutely necessary. With extrusions in long lengths, where it is impractical to ship in straight lengths and coiling in boxes or cartons causes distortion of the product, the product should be removed from the container when received and stored in straight lengths on shelves to preserve usability. Packaging is a complex area and should be given serious consideration. The table at right is to be considered only as a guide. Special packaging problems should be considered between purchaser and supplier.

Table 24

EXTRUSION PACKAGING

RMA Class	Drawing Designation	
1	P1	This class of product will be packaged to eliminate all possible distortion during transportation and storage. This may require special boxes, cartons, forms, cores, inner liners, or other special methods.
2	P2	This class of product will be packaged in corrugated containers or boxes. The quantity of the product packaged per container will be held to an amount which will not crush the lower layers from its own weight, but no forms, cores, inner liners, etc. are necessary.
3	P3	This class of product will be packaged in corrugated paper containers, boxes, crates, burlap bags or bundles, or on skids and pallets. This is the most economical method of packaging but may also produce the greatest distortion in the product.

Chapter 3

LATHE CUT

PURPOSE AND SCOPE

The purpose of this section is to provide the design engineer with sufficient information concerning the lathe cut manufacturing process that will permit him to select the design parameters for lathe cut products which will meet his needs. In addition, this section will outline the methods of specifying a lathe cut product and the tolerance capability that is available through current manufacturing processes.

What is a Lathe Cut?

A lathe cut product is manufactured from a cylindrical tube of rubber by inserting a mandrel into the cylindrical tube and cutting the finished dimensions with a knife while the mandrel is being turned at high speed in a lathe type machine.

Method of Manufacture

The cylindrical tube from which lathe cut products are cut may be produced by several manufacturing processes depending on design parameters such as size, quantity required, tolerances and material. The most common manufacturing processes used to produce this tube are:

a. Injection or compression molding
b. Extrusion with continuous vulcanization
c. Extruding the cylindrical profile, placing it on a curing mandrel sized to meet the required inside diameter and vulcanized in an open steam autoclave. This process generally requires the tube to be wrapped tight with a fabric material prior to vulcanization to keep the inside diameter in contact with the mandrel. Once the tube is vulcanized, the outside diameter must be ground to provide the proper wall or outside diameter dimension. This is accomplished by placing a mandrel inside the cylindrical tube and grinding the outside diameter to the specified size.

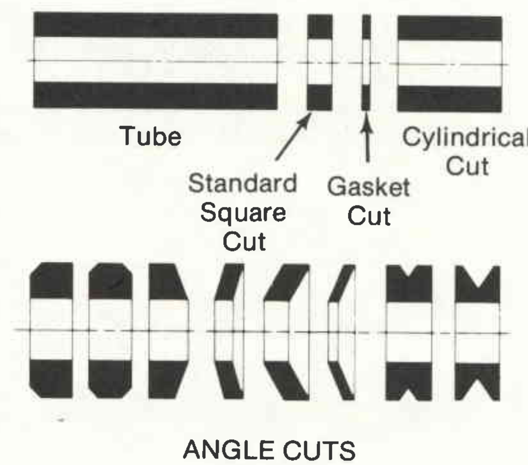
Uses

Lathe cut products are used in many applications such as: Seals, Drive Belts, Vibration Dampeners, Bumpers, Bushings and Insulators.

Design Configurations

Various cross sections are available for lathe cut parts as shown below. (Consult supplier for design specifications).

Figure 30



HOW TO SPECIFY A LATHE CUT PRODUCT

Because of the manufacturing methods (as described) required to produce a lathe cut part, it is very important for the design engineer to consider what are the most critical dimensions of the lathe cut part with respect to its application. The conventional lathe cut part with the cut 90° from the axis of the tube can be specified in one of the two following manners:

(1) Normal or most common method—
If the inside diameter is the most critical dimension to the function of the part, the lathe cut product will be specified by inside diameter ± tolerance, the wall thickness ± tolerance and cut thickness ± tolerance. The tolerances will be selected from Table 25.

(2) If the outside diameter is the most critical dimension to the function of the part, the lathe cut product will be dimensioned by outside diameter ± tolerance as measured over a fixed diameter mandrel that provides a minimum of 3% stretch and the cut thickness ± tolerance. The outside diameter tolerance for lathe cut parts specified by this method will be selected from Table 26. The cut tolerance will be selected from Table 25.

(3) If concentricity is critical to the function of the part, the tolerance will be selected from Table 27.

Table 25

INSIDE DIAMETER TOLERANCE

Drawing Designation		C1	C2	C3
RMA Class		Precision	Commercial	Non-Critical
I.D. (In.)				
Above	Included			
.200	.700	± .005	± .007	± .010
.700	1.500	.006	.010	.015
1.500	2.600	.010	.015	.025
2.600	5.000	.015	.025	.050
5.000	7.500	.025	.035	.070
7.500	9.000	.040	.060	.100
9.000	12.000	.050	.075	.125
I.D. (MM.)				
5.08	17.78	± .13	± .18	± .25
17.78	38.10	.15	.25	.38
38.10	66.04	.25	.38	.64
66.04	127.00	.38	.64	1.27
127.00	177.80	.64	.89	1.78
177.80	228.60	.76	1.14	2.29
228.60	304.80	1.02	1.52	2.54

NOTE: Tolerances for post cured lathe cut parts from silicone, polyacrylates and other materials usually require greater tolerances on the inside diameter. Consult supplier for tolerance requirements.

CUT THICKNESS TOLERANCE

Drawing Designation		C1	C2	C3
RMA Class		Precision	Commercial	Non-Critical
Cut (TK) (In.)				
Above	Included			
.015	.200	± .004	± .005	—
.200	.400	.006	.010	.015
.400	.500	.007	.015	.030
.500	.600	.008	.020	.045
.600	.700	.009	.025	.060
.700	1.000	.010	.030	.075
Cut (TK) (MM.)				
.38	5.08	± .10	± .13	—
5.08	10.16	.15	.25	.38
10.16	12.70	.18	.38	.76
12.70	15.24	.20	.51	1.14
15.24	17.78	.23	.64	1.52
17.78	25.40	.25	.76	1.91

TABLE 25 Concluded.
WALL THICKNESS TOLERANCE

Drawing Designation		C1	C2	C3
RMA Class		**Precision**	**Commercial**	**Non-Critical**
Wall (W) (In.)				
Above	Included			
.030	.200	± .004	± .007	—
.200	.300	.005	.010	.015
.300	.500	.007	.015	.020
Wall (W) (MM)				
.76	5.08	± .10	± .18	—
5.08	7.62	.13	.25	.38
7.62	12.70	.18	.38	.51

Figure 31

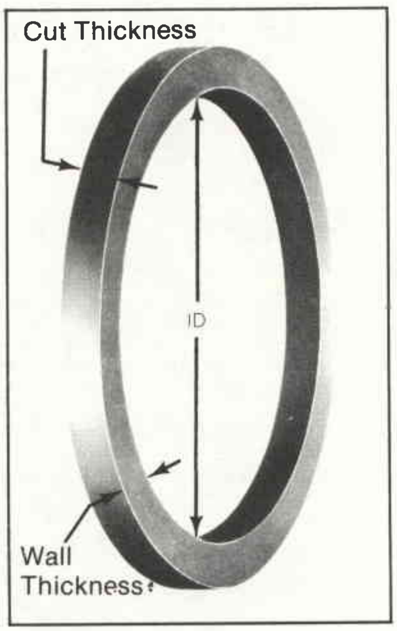


Table 26

OD TOLERANCE (MEASURED ON FIXED MANDREL)

Drawing Designation	C1	C2	C3
Wall Thickness inches	**Precision**	**Commercial**	**Non-Critical**
Above / Included			
.030 / .200	± .005	± .008	± .015
.200 / .300	.008	.012	.020
.300 / & over	.010	.015	.025
millimeters			
.76 / 5.08	± .13	± .20	± .38
5.08 / 7.62	.20	.30	.51
7.62 / & over	.25	.38	.64

NOTE: This chart is to be used only when outside diameter is the most critical dimension. The specification should be outside diameter ± tolerance from above chart when measured over a fixed diameter mandrel.

Example for C1
O.D. to measure 4.000 ± .008 dia. when measured over a 3.500 dia. mandrel.

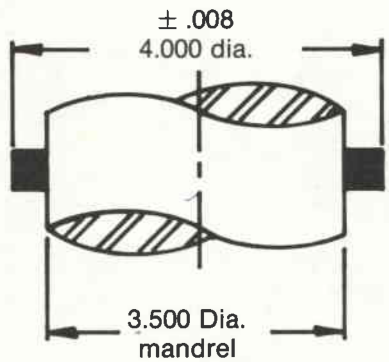


Table 27

STANDARDS FOR TOTAL INDICATOR READING (T.I.R.) TOLERANCE

Drawing Designation	C1	C2
Inside Diameter I.D. Inches	**Precision**	**Commercial**
Above / Included		
— / .500	.008	.008
.500 / 1.000	.008	.010
1.000 / 2.000	.008	.013
2.000 / & over	.008	.016
millimeters		
— / 12.70	.20	.20
12.70 / 25.40	.20	.25
25.40 / 50.80	.20	.33
50.80 / & over	.20	.41

Concentricity is the relationship of two or more circles or circular surfaces having a common center. It is usually designated as T.I.R. (total indicator reading) and is the total movement of the hand of an indicator set to record the amount that a surface varies from being concentric. (See example on page 31.)

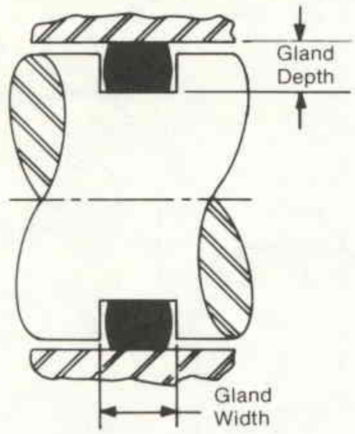
LATHE CUT PRODUCTS USED AS SEALS

When selecting a lathe cut product to fit an existing gland or when designing a seal gland in a new application, the relationship of the lathe cut seal cross section to the gland depth and width is of prime importance. The gland depth governs the amount of squeeze applied to the seal section, while the gland width affects the way the seal fills the gland.

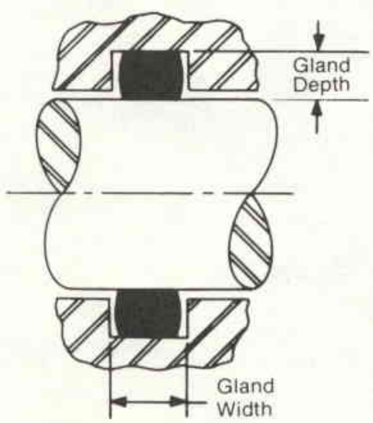
Nearly all applications of lathe cut seals fall into one of the four configurations shown below:

Figure 32

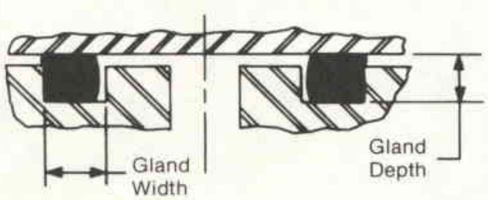
Four basic applications



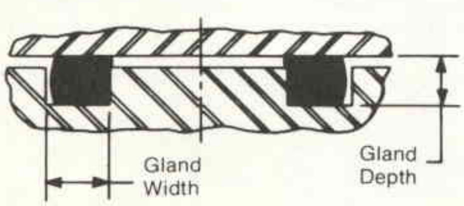
A — Assembled on a rod



B — Assembled in a bore



C — Face seal, internal pressure



D — Face seal, external pressure

The design chart, Table 28, provides suggested gland depths and widths for each of the five standard seal cross sections. The five standard cross sections are equivalent to the five standard cross sections for O-rings as specified in AS568. Slight variations in existing seal glands from the dimensions shown here are not uncommon. A variation of a few thousandths of an inch in an existing gland does not prevent the selection and application of a standard cross section seal.

Seal squeeze is radial for applications assembled on a rod (A) or in a bore (B). The gland is cut on the outside diameter of a piston or the inside diameter of a bore. Squeeze is obtained when the two mating surfaces are assembled.

For face seal application the gland is cut in the face of a flange or cover. Here consideration should be given to the direction of applied pressure. The seal should be sized to make contact with the low pressure side of the groove as installed. For internal pressure, the seal makes contact with the outside diameter of the gland (C). Conversely, for external pressure applications, the seal is selected to make contact with the inside diameter of the gland (D).

The design chart, Table 28, may be used as a guide in the design of special seals and glands. Particular attention should be given to seal squeeze and gland fill. The chart states the suggested amount of squeeze on the seal cross section necessary to insure reliable seal performance without overstressing the seal material.

Squeeze is added to the gland depth to determine the seal wall dimensions for radial applications. For face seal application, squeeze is added to the gland depth to determine the seal's cut thickness. (See Figure 33).

Next, consider the percent of fill which is the ratio of the cross sectional area of the seal to the cross sectional area of the gland. In most applications, the designed percent of fill is 80%. This provides ample space for the seal under applied squeeze and allows space for seal swell due to fluid and temperature effects. High pressure applications above 1500 psi, however, may require a greater percent of fill.

Starting with the one seal cross sectional dimension determined by squeeze, the other seal dimension can be determined to arrive at the desired percent of gland fill.

Inside diameter of the seal is determined by the diameter of the gland. For applications where the seal is assembled on a rod or as an external face seal, the inside diameter should make contact with the groove. When assembled in a bore or as an internal face seal, the outside diameter of the seal should make contact with the groove. In both cases, this is prior to assembly.

Table 28

AS 568 Dash No.	Nom. Cross Section	Actual Cross Section W x TK	Gland Depth	Gland Width	Inside Radius Max.	Clearance Gap Max.	Squeeze		
							Min.	Mean	Max.
	Dimensions in In.		+ .000 - .002	+ .005 - .005					
000 - 050	1/16"	.066 x .066	.057	.099	.015	.002	.005	.010	.015
106 - 170	3/32"	.099 x .099	.090	.146	.015	.0025	.005	.010	.015
201 - 284	1/8"	.134 x .134	.1225	.193	.025	.003	.0075	.0125	.0175
309 - 387	3/16"	.203 x .203	.187	.286	.030	.0035	.011	.017	.023
425 - 465	1/4"	.265 x .265	.240	.380	.030	.005	.020	.026	.032
	Dimensions in mm.		+ .00 - .05	+ .13 - .13					
000 - 050	1.59	1.68 x 1.68	1.44	2.51	.38	.05	.13	.25	.38
106 - 178	2.38	2.51 x 2.51	2.29	3.71	.38	.06	.13	.25	.38
201 - 284	3.18	3.40 x 3.40	3.11	4.90	.64	.08	.19	.32	.44
309 - 387	4.76	5.16 x 5.16	4.75	7.19	.76	.09	.28	.43	.58
425 - 465	6.35	6.73 x 6.73	6.10	9.65	.76	.13	.51	.66	.08

METRIC

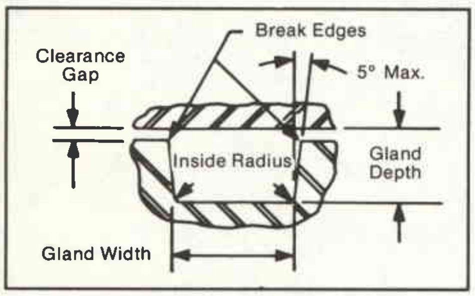
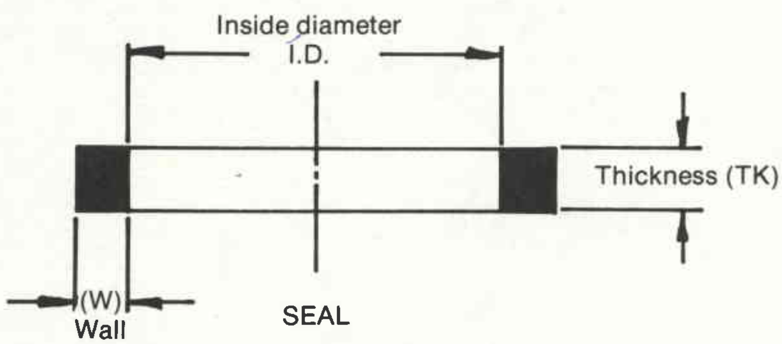
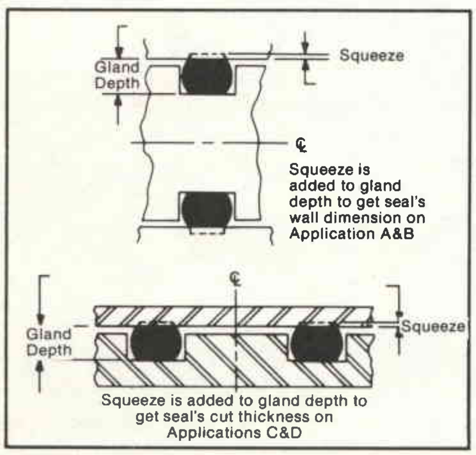


Figure 33





Chapter 4

CELLULAR RUBBER PRODUCTS

SPONGE AND EXPANDED • SHEET • MOLDED AND EXTRUDED

PURPOSE AND SCOPE

The purpose of this chapter is to acquaint the design engineer with the fundamentals of cellular rubber quality specifications.

Every effort has been made to place at the disposal of the design engineer and purchasing agent sufficient data to reconcile the requirements of the designers with the abilities of the manufacturers of cellular rubber products.

The sections that follow provide the background which is necessary to design and purchase open cell sponge and closed cell expanded rubber parts. Each section sets forth the commonly accepted specification symbols. By carefully determining the degree of perfection required, the design engineer will be able to specify the desired quality in terms which can be interpreted correctly by his supplier.

Open cell sponge* rubber has interconnecting cells, produced by expansion of gases from chemical reactions. Closed cell expanded* rubber has non-interconnecting cells, produced by the controlled release of inert gases such that the gases are entrapped as a multiplicity of separate bubbles in the rubber matrix. Open cell sponge rubber is manufactured in the forms of sheets or as molded products (strips or shapes). Closed cell expanded rubber is manufactured in the forms of sheets, molded shapes or extrusions.

The physical requirements and material specifications and designations for sponge and expanded cellular* rubbers are given in ASTM specification D-1056. For the convenience of all concerned, and to promote nationwide uniformity, it is strongly recommended that these grade designations, requirements and test methods be used wherever possible.

The scope of this section presents to the user the tolerances and standards the rubber manufacturers are normally able to maintain relative to the various areas as outlined in the summary of sections.

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*The terms, "cellular", "sponge", and "expanded" have been used, in past years, with various and sometimes conflicting meanings. The usage herein is in accordance with the generally agreed-upon and approved definitions in ASTM specification D-1566, and the glossary found at the close of this handbook. "Cellular rubber" is a generic term covering latex foam, urethane foam, sponge rubber, and expanded rubber. Only the sponge and expanded types of cellular rubbers are discussed in this chapter.

SUMMARY OF RMA DRAWING DESIGNATIONS CELLULAR RUBBER PRODUCTS

Drawing Designations

The design engineer should select and designate on the drawing a separate RMA class for dimensional tolerances of the particular product, finish, surface condition and packaging (also splicing and trimming, where applicable). If no class is specified, the rubber supplier will assume that commercial tolerances apply.

Table 29

DRAWING DESIGNATION FOR DIMENSIONAL TOLERANCES

	open cell die-cut open or closed-cell molded		closed cell silicone molded		closed cell die-cut sheet or strip		closed cell extruded irregular and cored	cored rectangular and regular	all lengths	closed cell tubing	
RMA Class	Thickness Table 31	Length & Width, Table 32	Thickness Table 33	Length & Width	Thickness Table 34	Length & Width, Table 35	cross section Table 36	cross section Table 37	Length Table 38	Inside Diameter Table 39	Wall Thickness Table 40
A					BTH A						
1	ATH 1	AL 1			BTH 1	BL 1	BEC 1	BER 1	BEL 1	BET 1	BEW 1
2	ATH 2	AL 2			BTH 2	BL 2	BEC 2	BER 2	BEL 2	BET 2	BEW 2
3	ATH 3	AL 3	STH 3	SL 3	BTH 3	BL 3	BEC 3	BER 3	BEL 3	BET 3	BEW 3
4	ATH 4	AL 4									

DRAWING DESIGNATIONS FOR OTHER STANDARDS

	Finish	Surface	Splice	Trim	Packaging
RMA Class	Table 41	Table 42	Table 43	Table 44	Table 45
A	F A				
1	F 1	R 1	S 1	T 1	P 1
2	F 2	R 2	S 2	T 2	P 2
3	F 3	R 3	S 3	T 3	P 3
4				T 4	P 4
5				T 5	

EXAMPLES OF USAGE OF RMA DRAWING DESIGNATIONS

Open-Cell Sponge Products

Example #1:
RMA-ATH 1, AL 2, T 2, F 2, R 2, P 2
Tight Thickness Tolerance, Commercial Length and Width Tolerances; Close Trim, Finish Suitable for Cementing; Good Surface; Small Container Packaging.

Example #2:
RMA-ATH 2, AL 1, T 1, F 2, R 2, P 1
Commercial Thickness Tolerance; Tight Length and Width Tolerance (like gasket going into mating stamping); Very Close Die or Hand Trim; Finish Suitable for Cementing; Good Surface; Special Packaging with Core; Dividers, etc.

Example #3:
RMA-ATH 2, AL 3, T 4, F 3, R 3, P 3
Commercial Thickness Tolerance; Loose Length and Width Tolerances (like Mold or Die Cut Space Filler Plug); Broad Trim; Finish not Important; Surface not as Important as Function; Commercial Packaging.

Example #4:
RMA-ATH 2, AL 2, S 2, T 3, F 2, R 2, P 2
Commercial Thickness Tolerance; Commercial Length and Width Tolerances; Commercial Splice; Moderate Trim; Finish Suitable for Cementing; Good Surface; Small Container Packaging.

Closed-Cell Expanded Products

Example #5:
RMA-BTH 2, BL 2, S 1, T 1, F 1, R 1, P 1
Commercial Thickness Tolerance, Commercial Length and Width Tolerances, Very Good Splice (like closed cell corner to weather strip); Very Tight Trim; Very Clean Surface; Smooth Finish; Special Packaging.

Example #6:
RMA-BTH 2, BL 1, S 2, T 2, F 2, R 2, P 2
Commercial Thickness Tolerance; Tight Length and Width Tolerances (as to mating part); Normal Splices (may be many as fabricated die-cut part); Commercial Trim; Finish Suitable for Cementing; Good Surface; Small Container Packaging.

TYPES OF PRODUCTS

SPONGE (OPEN CELL)

Sponge rubber is made by incorporating into the compound a gas-producing chemical such as sodium bicarbonate, which expands the mass during the vulcanization process. Sponge rubber is manufactured in sheets, molded strips, and special shapes. Sheets and parts cut from sheets will usually have a surface impression since sheets are usually molded against a fabric surface which allows air to be vented during the expansion of the sponge. Molded strips will have open cells exposed at the ends of the part unless otherwise specified. Die-cut parts will have open cells on all cut edges. On parts where open cell surfaces cannot be tolerated this should be so specified.

Trapped air, which may affect the finish, is a universal problem of sponge manufacturing due to the fact that sponge molds are only partially filled with uncured rubber, allowing for expansion to fill the mold. For this reason long and/or complicated cross sections may require vents or multiple splices to effect low reject percentages. To minimize trapped air it is common practice to use a considerable amount of a chemically inert dusting agent such as talc, mica, or starch, which is difficult to remove completely from the surface of the finished part, although molded closed cell parts prepared by transfer molding need not have this disadvantage.

In addition to a normal mold skin surface, some parts are manufactured with an applied solid rubber skin or coating to give more durable, water-resistant surface exposed to weathering. This is usually applied by calendering a thin sheet of solid rubber compound (0.005 in. — 0.040 in.; 0.12 — 1.0 mm) and applying it to a sheet of sponge compound and placing this in a mold suitably parted to form skin on the exposed surfaces of the part. Since the solid skin must stretch to cover the surface of the mold during the blowing of the sponge compound, there are practical limitations to designs which can be made by this process, as when skin stretches, the thickness decreases and may ultimately break through. In addition to the above method, an applied skin may be formed by dipping a molded and cured part in latex or cement and depositing a coating on the surface of the part, followed by suitable drying and curing. This coating may be built up to desired thickness by multiple dipping. Limitations on this method are those inherent in most dipping methods such as tendency to bridge slots or holes, loss of detail of molding, and uneven thickness of skin.

EXPANDED (CLOSED CELL)

Closed cell rubbers are made by incorporating gas forming ingredients in the rubber compound, or by subjecting the compound to high pressure gas such as nitrogen. Expanded rubbers are manufactured in sheet, strip, molded and special shapes by molding or extruding.

Closed cell sheets are generally made rectangular and of sufficient thickness to be split into several layers for die cutting. From this use is derived, for economic reasons, the term "skin one side or no sides, our option". Closer tolerances can usually be maintained on split sheets (no skin surfaces) than on sheets with a natural skin. Unless otherwise specified, the presence of skin on the top or bottom surfaces of sheet and strip expanded rubber is optional. Die cut parts will have exposed cells on all cut edges. On parts where exposed cell surfaces cannot be tolerated (appearance or abrasion, etc.) this should always be so specified.

Extruded closed cell rubber is made by extruding the raw compound through a die which determines the shape of the section. The extruded stock is carried from the die by a conveyor system in a continuous process through vulcanizing chambers. As it moves through the vulcanizing chambers the heat causes the blowing agent to decompose to produce an inert gas which expands the extrusion. This is followed by a continuous cure until vulcanization is complete. On emerging from the vulcanization chamber it is cooled to stabilize it dimensionally, and such subsequent operations performed as punching holes, slots, coating, dribaking, buffing and cutting to specific lengths or winding onto reels in continuous lengths of any reasonable footage that the customer may desire.

Characteristics of Extruded Closed Cell Rubber are:

1. The surface of the extruded section has a natural skin that is clean and smooth.
2. It is possible to produce the part in continuous lengths.
3. A great variety of complex and irregular shapes may be produced.
4. Air chambers or hollowed out designs may be utilized, giving the advantage of reduction in weight of material. The design engineer, by properly designing the cross section with maximum air chamber space, can generally achieve considerable advantage in terms of performance and compression deflection.

Molded closed cell parts are manufactured similar to open cell molded sponge. They require venting of trapped air and the necessary use of inert dusting powder which is difficult to remove completely from the surface of the finished part. Long complicated sections may require vents or multiple splices to effect low reject percentages.

Distinct advantages of closed cell products are their low water absorption characteristics, providing a tight seal and the ability to conform to curves, corners and varying cross-sections without bridging or creasing. This is attributable to the closed cells which do not collapse, losing air as in open cell sponge, and yet deform (compression set) sufficiently to conform tightly to irregular surfaces. Its thermal value is utilized in insulation applications.

Design of extruded or molded shapes (uncored or cored) radically affects the compression of parts and leads to greater or less apparent compression set values.

CELLULAR SILICONE RUBBER

Cellular silicone rubber in sheet, molded or extruded forms can be made by processes similar to those for other cellular rubbers. A post-cure period in a hot-air oven is usually used to insure complete vulcanization. Because dimensions can undergo some change during this post-cure wider dimensional tolerances must be allowed, particularly on molded items. Suggested dimensional tolerances for molded cellular silicone rubbers are given in Table 33. Cellular silicone rubber is almost always produced with a closed-cell structure.

COMPRESSION SET TEST

A compression set test has been in use for a long period of time on solid rubber and open-cell sponge rubber products. (50% compression, of sponge, for 22 hours at 158° F (70° C)). The set test is used to determine the quality of those products and their applicability to certain types of usage. Because of this extensive use of the set test on other materials, it is frequently applied to closed cellular materials for the same purposes, namely to determine the quality and applicability of the closed cellular material for general usage or for specific jobs. However, due to the special characteristics of the closed cellular structure, the compression set test has an entirely different effect on closed cellular materials and requires an entirely different interpretation. The differences in application and interpretation of the compression set test on open and closed cellular materials are shown in the comparative tabulation in Table 30.

Table 30

COMPRESSION SET COMPARATIVE TABLE

Open Cells	Closed Cells
1. Air is free to pass through open cells. There is no effect of the 158°F (70°C) test temperature on the air pressure in the cells.	1. Air is not free to pass through the closed cells. The 158°F (70°C) test temperature causes an increase in air pressure in the closed cells.
2. All of the compressing pressure is on the rubber during the test.	2. Part of the compressing pressure is on the rubber but part of it is on the air in the cells during the test.
3. There is no air diffusion effect through the cell wall structure.	3. During the time that the closed cell structure is under pressure, in the test there is some air diffusion through the thin cell walls. (This is the same diffusion effect that occurs when air pressure decreases in an automobile tire over a period of time, even though there is no specific leak in the tube. This effect is a basic characteristic of the rubber or synthetic polymer. It cannot be changed significantly by the cellular rubber product manufacturer.).
4. The rubber is free to recover immediately after the test. Air can go back into the open cells immediately.	4. The rubber is not free to recover after the test. Air can not go back into the closed cells immediately.
5. The sample retains the compression set after the test.	5. The sample continues to recover long after the test period is over.
6. The compression set test result indicates the state of cure of the rubber sample. An under-cured sample shows a high compression set.	6. The compression set test result does not necessarily indicate the state of cure of the sample. It is more an indication of the amount of air that has diffused from the closed cells and has not yet diffused back.
7. On samples which are otherwise equivalent, the test results are not affected greatly by the thickness of the sample.	7. On samples which are equivalent in other respects, the test results are greatly affected by the thickness of the sample tested. This is because of the diffusion effect as noted above.
8. The compression set test result is not directly affected by the hardness of the open cell sponge.	8. The compression set test result is affected by the hardness of the sample, harder materials showing lower percentages of set. This is because in the harder material the rubber portion supports a relatively higher amount of the total pressure in comparison with the air cells.

It is because of this very great difference in behavior of open cell materials vs. closed cell materials in the compression set tests, that ASTM D-1056 contains a modified set test (22 hr. at room temp., with 24 hr., recovery) on these materials. For the same reason, several military specifications on closed cellular materials do not use the standard test as indicated above but have various special test requirements which take into consideration the differences of the properties of the closed cellular materials.

STANDARDS FOR DIMENSIONAL TOLERANCES

Introduction

In this section the reader will find standard tolerances for basic dimensions of sponge and expanded rubber parts. Due to the complexity of design (coring, thick and thin cross-section in each part, etc.), it is recommended that tolerances be established for each part, between the manufacturer and customer, only after studying the clearances and the particular function desired in practical use. It should be noticed that tolerances are plus or minus and are related to the actual or theoretical center of the part. In extruded sections or molded strips it is a good practice to use 10 times size shadow-graphs with tolerances emanating from a specific centerline. In all discussion of tolerances the high compressibility of sponge and expanded rubber parts, as different from solid molded rubber parts, must be taken into consideration as well as the ease of stretching or crowding into sections where design has called for cellular sponge or expanded parts.

Specific information on factors affecting dimensions and tolerances of sponge and expanded rubber materials is presented in the following paragraphs.

Tolerances are given in Tables 31 through 40.

FACTORS AFFECTING TOLERANCES

Shrinkage

All sponge and expanded rubber have some amount of shrinkage after manufacture. The mold designer and rubber compounder must estimate the amount of shrinkage and incorporate this allowance into the mold cavity size, or extrusion die. However, the shrinkage is also a variable in itself, and is affected by such things as rubber batch variance, state of vulcanization, temperature, pressure, and other factors. The shrinkage of various compounds varies widely. As a result, even though the mold or die is built to anticipate shrinkage, there remains an inherent variability which must be covered by adequate dimensional tolerance. Complex shapes may also cause irregular shrinkage.

Expanded (closed cell) materials are particularly affected by the gas under pressure (when first manufactured) in the individual cells.

Optimum conditions would be where the internal pressure is finally equal to atmosphere pressure. Manufacturers stabilize their products by prolonged room temperature aging or by suitable oven conditioning before cutting to dimensions for shipment or fabricating. Since gas is trapped in each closed cell, due consideration should be given to possible changes in dimension resulting from atmospheric temperature and pressure variations.

Mold and Die Design

Molds and dies can be designed and built to varying degrees of precision.

With any type of mold or die, the builder must have some tolerance, and therefore each cavity will have some variance from the others. The dimensional tolerances on the part must include allowance for this fact. For molds or dies requiring high precision, the machining and design work must be done accordingly.

High pressure is not required for molded cellular pieces allowing the use of cast aluminum molds. For parts which require close register, greater precision can be obtained by other types of mold construction such as self-registering cavities. Tolerances, and quality of finished article are adversely affected by designs which have undercuts, abrupt changes in volume of cross-section, feather edges and sharp corners. A realistic consideration of tolerances required on the part will usually be more economical, and will result in a more satisfactory production job.

For extrusion dies the same general factors apply.

Trim and Finish

Many different methods are used to remove flash and otherwise complete the finished part. This section is concerned with the effects of finishing methods on dimensions and tolerances.

The objectives of most trimming and finishing operations are to remove the flash, plugs or other rubber material which are not a part of the finished piece. Often this is possible without affecting the important dimensions, but in other instances some material is removed from the piece itself. It is therefore necessary to give consideration to trimming in setting dimensional tolerances.

In expanded products where hot splicing is necessary, there may be irregularity in finish and tolerances due to the temperature of splicing which causes expansion when heating and later contraction of the gas cells on cooling, and also due to pressure which could cause some changes in dimensions.

Core Dimensions

Core dimensions are determined by the cores in the mold which in turn form the interior of a hollow article.

A core may be suspended individually in a cavity by bars, or pins, or attached to a core bar or other multiple unit. The nature of the part may prevent rigid suspension, causing the pressure of the stock to deflect the core, such as long tubing.

Parts may be deformed or stretched in removal from some types of cores. Realistic tolerances should be established between purchaser and supplier.

On thicker sections of expanded (closed cell) rubber, hollow extrusions should be considered for better control of compression and less material.

Floating of the I.D. (inside diameter) with subsequent variation in wall thickness may not adversely affect the overall dimensions and functions of the part.

Rubber Insert Dimensions

These are the dimensions from a rubber surface to an insert molded to or in the rubber. The accuracy with which these dimensions can be held depends upon the mold construction, method of locating the insert, and the tolerances of the insert. Dimensional control is difficult when inserts are for an odd shape which causes difficulty in loading the mold. The rubber supplier may wish to make slight revisions on an insert to allow use of locating pins, support pins or other devices to prevent inserts from drifting or "floating". Insert irregularities such as edges at formed radii, irregular edges from dies, or shearing often prevent good fit in the mold. The supplier's mold engineers can offer information and help on these details.

Other

There are other items which affect dimensions. The ease of stretching or compressing of cellular rubber parts can very readily affect the measurements of length and cross section which in turn affect the tolerances that may be set.

In die cutting closed cell parts over 1/2 in. (12.5 mm) thick, a dish effect occurs on the edges which may affect close tolerances on width and length.

The method of packaging may affect flatness, diameters and other qualities. No attempt has been made to enumerate all the other factors, merely to call attention to the fact that cellular rubber is compressible, pliable, semi-plastic material. Therefore, the dimensions may not be as important as with a more rigid material.

ENVIRONMENTAL STORAGE CONDITIONS

TEMPERATURE

Rubber, like other materials, changes in dimension with changes in temperature. It has a coefficient of expansion which varies with different formulations. Compared to other materials the coefficient of expansion of rubber is high. To have agreement in the measurement of products that are critical or precise in dimension, it is necessary to specify a temperature at which the parts are to be measured and the time required to stabilize the part at that temperature.

HUMIDITY

Some rubber materials absorb moisture. Hence the dimensions are affected by the amount of moisture in the product. For those products which have this property, additional tolerance must be provided in the dimensions. The effect may be minimized by stabilizing the product in an area of controlled humidity and temperature for a period not less than 24 hours.

TOLERANCE TABLES

Table 31

Tolerances on thickness dimensions of open cell sponge, die-cut, sheet, or strip; and open or closed cell molded cellular rubber.

THICKNESS

RMA Class	1	2	3	4
RMA Drawing Designation	ATH 1	ATH 2	ATH 3	ATH 4
Inches		Tolerance		
Above-Incl.				
0 - .125	±.0125	±.016	±.020	±.025
.125 - .250	.016	.020	.025	.0315
.250 - .500	.020	.025	.0315	.040
.500 - 1.00	.025	.0315	.040	.050
1.00 - 2.00	.0315	.040	.050	.055
2.00	2%	2.5%	3%	3.5%
Millimeters		Tolerance		
Above-Incl.				
0 - 3.15	±0.32	±0.4	±0.5	±0.63
3.15 - 6.3	0.4	0.5	0.63	0.80
6.3 - 12.5	0.5	0.63	0.80	1.00
12.5 - 25	0.63	0.80	1.00	1.25
25 - 50	0.80	1.00	1.25	1.50
50 -	2%	2.5%	3%	3.5%

Table 32

Tolerances on length and width dimensions of open cell sponge, die-cut, sheet or strip; and sectional and linear dimensions for open or closed cell molded cellular rubber.

LENGTH AND WIDTH

RMA Class		**1**	**2**	**3**	**4**
RMA Drawing Designation		**AL 1**	**AL 2**	**AL 3**	**AL 4**
Inches			**Tolerance**		
Above	Incl.				
0	.25	± .010	± .016	± .025	± .040
.25	.50	.016	.025	.040	.063
.50	1.00	.025	.040	.063	.080
1.00	2.00	.040	.063	.080	.100
2.00	4.00	.063	.080	.100	.125
4.00	8.00	.080	.100	.125	.160
8.00	16.00	.100	.125	.160	.200
16.00	32.00*	.125	.160	.200	.240
32.00	64.00*	.4%	.5%	.63%	.8%
64.00	128.00*	.8%	1.0%	1.25%	2.0%
128.00*		1.6%	2.0%	2.5%	3.0%
Millimeters			**Tolerance**		
Above	Incl.				
0	6.3	± 0.25	± 0.4	± 0.63	± 1.0
6.3	12.5	0.40	0.63	1.0	1.6
12.5	25	0.63	1.0	1.6	2.0
25	50	1.0	1.6	2.0	2.5
50	100	1.6	2.0	2.5	3.2
100	200	2.0	2.5	3.2	4.0
200	400	2.5	3.2	4.0	5.0
400	800*	3.2	4.0	5.0	6.2
800	1600*	0.4%	0.5%	0.63%	0.8%
1600	3200*	0.8%	1.0%	1.25%	2.0%
3200		1.6%	2.0%	2.5 %	3.0%

METRIC

*Accurate measurement of lengths is difficult because these materials stretch or compress easily. Where close tolerances are required on long lengths, a specific technique of measurement should be agreed upon by purchaser and manufacturer.

Note: Class 1 tolerances are not recommended for the softer grades of material, below 9 p.s.i. (63 kPa) compression-deflection.

Table 33

Tolerances on thickness, length and width dimension of molded closed cell silicone cellular rubber.

RMA Class	3
RMA Drawing Designation	STH 3 and SL 3
Inches	**Tolerance**
Above-Incl.	
0 - .125	+ .032-.016
.125 - .250	± .032
.250 - .500	.040
.500 - 1.000	.050
1.000 - 4.000	.063
4.000 -	± 3%
Millimeters	**Tolerance**
Above-Inc.	
0 - 3.15	+ 0.8 - 0.4
3.15 - 6.3	± 0.8
6.3 - 12.5	1.0
12.5 - 25	1.25
25 - 100	1.6
100	± 3%

Table 34

Tolerances on thickness dimensions of die-cut sheet or strip expanded, closed cellular rubber.

THICKNESS

RMA Class		A	1	2	3
RMA Drawing Designation		BTH A	BTH 1	BTH 2	BTH 3
Inches			**Tolerance**		
Above	Incl.				
0	.125	± .016	+ .032-.016	± .032	± .040
.125	.25	.025	± .032	.040	.063
.25	.50	.032	.040	.063	.100
.5	1.0	.050	.063	.100	.160
1.0		4.0%	6.3%	10%	16%
Millimeters			**Tolerance**		
Above	Incl.				
0	3.15	± 0.40	+ 0.80-0.40	± 0.80	± 1.0
3.15	6.3	0.63	± 0.80	1.0	1.6
6.3	12.5	0.80	1.0	1.6	2.5
12.5	25	1.25	1.6	2.5	4.0
25		4.0%	6.3%	10%	16%

Table 35

Tolerances on length and width dimensions of die-cut sheet or strip, expanded, closed-cellular rubber.

LENGTH AND WIDTH

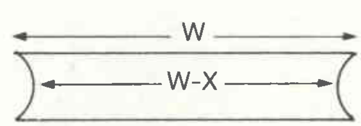
RMA	**1**	**2**	**3**
RMA Drawing Designation	**BL 1**	**BL 2**	**BL 3**
Inches	**Tolerances**		
For thicknesses up to .25 inch*			
under 1.0 1.0 to 6.3 over 6.3	± .025 .032 .63%	± .032 .040 1.0%	± .040 .050 1.6%
For thicknesses over .25 to .50 inch*			
under 1.0 1.0 to 6.3 over 6.3	± .032 .040 .63%	± .040 .050 1.0%	± .050 .063 1.6%
For thicknesses over .50 inch*			
under 1.0 1.0 to 6.3 over 6.3	± .040 .050 .63%	± .050 .063 1.0%	± .063 .080 1.6%

RMA Class	**1**	**2**	**3**
RMA Drawing Designation	**BL 1**	**BL 2**	**BL 3**
Millimeters	**Tolerances**		
For thicknesses up to 6.3 mm*			
under 25 25 to 160 over 160	± 0.63 0.80 .63%	± .080 1.0 1.0%	± 1.0 1.25 1.6%
For thicknesses over 6.3 to 12.5 mm*			
under 25 25 to 160 over 160	± 0.81 1.0 .63%	± 1.0 1.25 1.0%	± 1.25 1.6 1.6%
For thicknesses over 12.5 mm*			
under 25 25 to 160 over 160	± 1.0 1.25 .63%	± 1.25 1.6 1.0%	± 1.6 2.0 1.6%

*Separate schedules of length and width tolerances are listed for different thicknesses of these materials because of the "dish" effect in die-cutting. This is more noticeable as the thickness increases. As shown in the drawing below, the "dish" effect is a concavity of die-cut edges (due to the squeezing of the material by the pressure of the cutting die).

Figure 34

The width "W", (or length) at the top and bottom surface are slightly greater than the width "W-X" at the center.



Note: Class 1 tolerances should not be applied to the softer grades of material, below 9 p.s.i. (63 kPa).

Table 36

Tolerances on cross-sectional dimensions of irregular and cored shapes of extruded, expanded, closed-cellular rubber. Class 1 tolerances in Table below are recommended only for high volume, tight tolerance products for automotive applications.

CROSS SECTION

RMA Class		1*	2	3
RMA Drawing Designation		**BEC 1**	**BEC 2**	**BEC 3**
Inches			**Tolerance**	
Above	Incl.			
0	.25	± .016	± .020	± .025
.25	.50	.025	.040	.050
.50	1.0	.050	.080	.100
1.0	1.6	.080	.125	.160
1.6		6%	8%	10%

RMA Class		1*	2	3
RMA Drawing Designation		**BEC 1**	**BEC 2**	**BEC 3**
Millimeters			**Tolerance**	
Above	Incl.			
0	6.3	± 0.4	± 0.5	± 0.63
6.3	12.5	0.63	1.0	1.25
12.5	25	1.25	2.0	2.5
25	40	2.0	3.2	4.0
40		6%	8%	10%

*Class 1 tolerances should not be applied to the softer grades of material; below 9 p.s.i. (63 kPa) compression deflection.

Table 37

Tolerances on cross-sectional dimensions of cored, rectangular or other regular shapes of extruded, expanded, closed cellular rubber.

CROSS SECTIONAL DIMENSION
(width, thickness, or diameter)

RMA Class		1	2	3
RMA Drawing Designation		**BER 1**	**BER 2**	**BER 3**
Inches			**Tolerance**	
Above	Incl.			
.125	.50	± .032	± .032	± .040
.50	1.0	.050	.050	.080
1.0	2.0	.063	.080	.160
2.0	3.15	.100	.125	.200
3.15		6%	8%	10%

RMA Class		1	2	3
RMA Drawing Designation		**BER 1**	**BER 2**	**BER 3**
Millimeters			**Tolerance**	
Above	Incl.			
3.2	12.5	± 0.8	± 0.8	± 1.0
12.5	25	1.25	1.25	2.0
25	50	1.6	2.0	4.0
50	80	2.5	3.2	5.0
80		6%	8%	10%

Table 38

Tolerances on cut lengths of all extruded, expanded, closed cellular rubber products.
LENGTH

RMA Class		1*	2	3
RMA Drawing Designation		**BEL 1**	**BEL 2**	**BEL 3**
Inches			**Tolerance**	
Above	Incl.			
0	3.15	± .063	± .063	± .125
3.15	6.3	.125	.125	.250
6.3	12.5	.250	.250	.500
12.5	25**	2%	.500	1.000
24	50**	2%	1.000	2.000
50		2%	3%	4%

RMA Class		1*	2	3
RMA Drawing Designation		**BEL 1**	**BEL 2**	**BEL 3**
Millimeters			**Tolerances**	
Above	Incl.			
0	80	± 1.6	± 1.6	± 3.2
80	160	3.2	3.2	6.3
160	315	6.3	6.3	12.5
315	630**	2%	12.5	25
630	1250**	2%	25	50
1250		2%	3%	4%

*Class 1 tolerances should not be applied to the softer grades of material, below 9 p.s.i. (63 kPa) compression deflection.

**Accurate measurement of long lengths is difficult because these materials stretch or compress easily. Where close tolerances are required on long lengths, a specific technique of measurement should be agreed upon between purchaser and manufacturer.

Table 39

Tolerances on Inside Diameter of Extruded Closed Cellular Tubings.
INSIDE DIAMETER

RMA Class		1	2	3
RMA Drawing Designation		**BET 1**	**BET 2**	**BET 3**
Inches			**Tolerance (All plus no minus)**	
Above	Incl.			
0	0.50	+ .063	+ .063	+ .125
0.50	1.0	.100	.125	.250
1.0	2.0	.200	.250	.400
2.0	4.0	.250	.400	.500
4.0		.400	.500	.630

RMA Class		1	2	3
RMA Drawing Designation		**BET 1**	**BET 2**	**BET 3**
Millimeters			**Tolerances (All plus no minus)**	
Above	Incl.			
0	12.5	+ 1.6	+ 1.6	+ 3.2
12.5	25	2.5	3.2	6.3
25	50	5.0	6.3	10
50	100	6.3	10	12.5
100		10	12.5	16

Table 40

Tolerances on Wall Thickness of Extruded Closed Cellular Tubings.
WALL THICKNESS

RMA Class	**1**	**2**	**3**
RMA Drawing Designation	**BEW 1**	**BEW 2**	**BEW 3**
Inches	**Tolerances (All plus no minus)**		
under 0.63	+ .063	+ .125	+ .200
.063 and over	.125	.200	.250

RMA Class	**1**	**2**	**3**
RMA Drawing Designation	**BEW 1**	**BEW 2**	**BEW 3**
Millimeters	**Tolerances (All plus no minus)**		
under 16	+ 1.6	+ 3.2	+ 5.0
16 and over	3.2	5.0	6.3

STANDARDS FOR FINISH AND SERVICE CONDITION

SPONGE (OPEN CELL)

In order to better understand the standards set for finish and appearance of sponge products, some of the peculiarities involved in their manufacture affecting these characteristics should be examined.

As mentioned in the discussion, one of the major problems in manufacturing molded sponge items is "trapped air". Unlike solid rubber items, the mold is not loaded to capacity, but only a fraction of the mold is filled with raw compounds, and during the vulcanization process the raw compound is expanded by the action of the blowing agent so that it fills the mold; consequently, when a sponge mold is closed, it includes a volume of air not filled by the stock. Unless this air is dissipated by venting, or by the use of a dust such as mica, "trapped air" leaves depressions in the surface of the cured sponge item caused by the pressure of this air which has been pocketed in various locations in the cavity. It is generally impractical to vent a mold in a sufficient number of locations to bleed out all of this air plus the gases chemically generated in sponge itself. Therefore, it has become common practice in the sponge industry to use a generous quantity of finely ground mica which due to its plate-like crystalline structure, has the facility to bleed out air more efficiently than any other dusting pigment known.

The mica dust remaining on the surface of the cured sponge item is impossible to remove completely in any cleaning operation that would be economically feasible. In the case of black-colored products, the mica dust tends to make it appear gray because of its own light color. The mica is very insoluble and cannot be washed off completely. All sponge manufacturers have devised cleaning methods to remove the excess dust but still some traces are left on the surface. In most instances this is not a functional defect. If the sponge item is to be adhered to another surface by cementing, an excess amount will interfere with good adhesion. On other surfaces it may act as a lubricant and can be functionally beneficial. If the user of a sponge item insists on absolute freedom from dust, it has the effect of forcing the manufacturer to use little or no dust in the molding, which in turn induces surface defects in the finished product due to "trapped air" such as pitted surfaces and lack of sharp definition, especially on corners and edges.

In the case of automotive weatherstrip and certain gaskets, a thin layer of dense skin is specified over all or part of the surface of the sponge item to give it added resistance to abrasion, ozone and other aging factors. On parts requiring such a skin, it is desirable to design so as to avoid an "under cut" condition, which generally causes the skin to stretch so that it weakens and breaks, exposing the sponge to the surface. If such a condition cannot be avoided in the design of the part, then it is desirable to permit the manufacturer to repair such a spot of broken skin with a "fix" coating to cover and protect the sponge at such points.

Another fairly common surface defect which is usually not a functional defect is the so-called fold or crease in the dense skin on a sponge part. This is generally caused by the raw skin sagging into the soft sponge due to the heat of vulcanization and when the expansion takes place and fills the mold cavity, the dust that was on the surface keeps the skin from knitting together thus leaving a fold. This condition can sometimes be corrected by proper compounding, but in certain designs, it becomes difficult, if not impossible, to correct completely.

Another common condition in sponge parts is known as a void. A void, as the name implies, is the lack of substance in a given space. Since sponge is a cellular structure it is not uncommon for the gases generated, which produce this cellular structure, to accumulate in a small pocket and therefore cause an extra large cell to be formed which when depressed feels as though there is nothing there.

EXPANDED (CLOSED CELL)

Sheets of closed cellular rubber are usually split from thicker "buns" of the product. Closer dimensional tolerances can usually be maintained by splitting than by molding directly to the desired thickness. Therefore these sheets, and parts die cut or fabricated from them frequently have no skin surfaces.

In general the finish and surface appearance of extruded and molded closed cell parts are smoother, cleaner, less subject to surface pock marks and voids than open cell products.

Extruded closed cell strips do not have the surface sheen of solid rubber extrusions since the cells do run close to the surface. However, they require little or no dusting powders so are clean and free of trapped air marks and other surface defects associated with open cell sponge.

Molded closed cell parts do require a dusting lubricant but not as much as open-cell molded parts and generally clean better. Also the surface appearance because of the extremely fine closed cells is considerably smoother and has less trapped air marks.

A surface defect which is usually not a functional defect is the so-called fold or crease in the molded natural skin surface of the closed cell molded part. This is apt to occur in sections of considerable variation in cross sectional areas. As the closed cell material expands it may fold over on itself and may not completely knit together due to mold lubricating dust on the part. This condition can sometimes be corrected by proper compounding, but in certain designs, it becomes almost impossible to correct completely.

Table 41

SPONGE AND EXPANDED RUBBER FINISH

RMA Class	Drawing Designation	
A	FA	All surfaces to be washed and totally free of dust and lubricants.
1	F1	All surfaces to be cleaned and free of loose dusting agents and mold lubricants, such as mica, talc, starch etc.
2	F2	Cementing surfaces shall be cleaned and free of loose dusting agents and mold lubricants. Other surfaces shall be free of excessive dusting agents. Cleaning can be by wiping, tumbling, etc. unless washing is specified.
3	F3	Surfaces may have a small amount of loose dusting agents.

Table 42

SPONGE AND EXPANDED RUBBER SURFACE CONDITION

RMA Class	Drawing Designation	
1	R1	Surfaces shall be smooth and free of imperfection.
2	R2	Surfaces shall be free of pits, pock marks, foreign matter.
3	R3	Surfaces may have imperfections which do not affect the functions of the parts.

For a more detailed treatment of this subject, refer to Specification MIL-STD-293 entitled "Visual Inspection Guide for Cellular Rubber Items."

Table 43

SPONGE AND EXPANDED RUBBER SPLICING

RMA Class	Drawing Designation	
1	S1	Good alignment, and appearance.
2	S2	Good quality for normal commercial application. (a) Slight variations in alignment. (b) Loose cement spew near seam removed. (c) Slight separation not affecting strength of joint permissible. (d) Parting line flash trimmed to within 0.06 in. (1.6 mm).
3	S3	Passable quality standards. (a) Slight variations in alignment. (b) Mold imperfections not affecting strength of joint allowed. (c) No removal of excess vulcanizing cement. (d) Slight separation not affecting strength of joint permissible.

The trimming of molded parts may be accomplished by hand, machine or die. Due to the softness and resilience of expanded rubber, it is difficult to trim very closely without being extremely careful or occasionally cutting into the part. Multiplane parting lines generally necessitate hand trimming while single plane parting allows for more economical machine or die trimming.

Table 44

SPONGE AND EXPANDED RUBBER TRIMMING

RMA Class	Drawing Designation	
1	T.016 (T.40 mm)	.016 in. (0.4 mm) Flash allowable
2	T.032 (T.80 mm)	.032 in. (0.8 mm) Flash allowable
3	T.063 (T1.6 mm)	.063 in. (1.6 mm) Flash allowable
4	T.125 (T3.20 mm)	.125 in. (3.2 mm) Flash allowable
5	T $\propto$	No trim required (tear trim)

STANDARDS FOR PACKAGING

When sponge and expanded rubber parts are packaged, it is for the sole purpose of transportation from the supplier to the consumer. Packaging usually causes some distortion of the sponge and expanded rubber parts which, if used in a reasonable length of time, does not permanently affect the part. However, when sponge and expanded rubber parts are held in a distorted position for a prolonged period of time, permanent set may cause permanent distortion and result in unusable parts. Any product in which distortion may make the part unusable should be specified and packaged by such methods as will prevent distortion. Where it is impractical to ship in long straight lengths of sponge and expanded extrusions and where coiling in boxes or cartons causes distortion of the product, the product should be removed from the container when received and stored in straight lengths on shelves to preserve usability.

Table 45

PACKAGING OF ALL SPONGE AND EXPANDED PRODUCTS

RMA Class	Drawing Designation	
1	P1	This class of product must be packaged to eliminate all possible distortion during transportation and storage. This may require special boxes, cartons, forms, cores, inner liners, or other treatment.
2	P2	This class of product must be packaged in corrugated containers or boxes. The quantity of the product packaged per container must be held to an amount which will not crush the lower layers from its own weight, but no forms, cores, inner liners, etc. are necessary.
3	P3	This class of product must be packaged in corrugated containers or boxes in lengths, coils or pieces, but to the weight limit of the container without regard to crushing the product by its own weight.
4	P4	This class of product may be packaged in corrugated containers, boxes, crates, burlap bags or bundles, or on skids and pallets. This is the most economical method of packaging but may also produce the greatest distortion in the product.

QUALITY CONFORMANCE

PURPOSE AND SCOPE

This chapter has been developed to provide quality conformance guidelines that may be used in conjunction with design standards for Molded, Extruded, Lathe Cut, and Sponge and Expanded Rubber products. The intent is to establish and define uniform quality assurance practices applicable to these categories of rubber products.

Since conformance to quality standards has continued to play an increasingly important role in the sale, procurement, and usage of products, assurance of quality conformance has become a major element of the manufacturing function. The large number of items and materials produced within the rubber industry today makes necessary consideration of product characteristics prior to establishment of contractual quality requirements.

A Design Engineer can specify requirements to an exacting degree by using appropriate classifications for design quality as well as material tests such as those published by the American Society for Testing and Materials, Society of Automotive Engineers and others. It is important that the customer convey to the vendor total information about the operating conditions that the product will encounter.

The reference section of this Handbook page has a number of books, standards, etc., noted that apply to Quality Control and Quality Assurance.

The sections of this Handbook on Molded, Lathe Cut, Extruded and Cellular Products provide tolerance tables for dimensions and for some properties that are frequently specified. The reader is referred to the indices of the sections on the particular type products in which he has interest.

INSPECTION AND TESTING EQUIPMENT AND METHODS

GENERAL TESTING

Much of the standard inspection equipment found in a general inspection laboratory can be adapted to the gauging of rubber products. Others are not applicable to non-rigid materials.

In case of dispute regarding dimensional characteristics, it is recommended that optical comparators be used in preference to normally used micrometers, dial indicators, and other instruments that depend on spring pressure, mechanical interference, or feel, to measure flexible rubber surfaces.

If the product and laboratory storage conditions are conducive to maintaining standard samples for visual and dimensional characteristics, these should be kept on hand in order to make comparisons if it is believed that shipments are not meeting specifications. Rechecking of the standards will quickly confirm, if the inspection equipment is operating properly or if the product is truly out of specification. The aging characteristics of the rubber product must be recognized and it may be necessary to arrange for new standard pieces periodically.

For such other characteristics as hardness, spring rate (radial, axial, torsional), dynamic stiffness and dampening coefficient, bench life test, etc., it is essential that the explicit details of how these measurements are to be made, the conditions under which they are to be made, and the fixtures to be used, are worked out and agreed to by both buyer and vendor. Correlation of results between the buyer's inspection or quality control departments and the vendor's comparable departments should begin at the design stage and be repeated periodically thereafter.

Wherever possible, the conditions of material testing shall be in accordance with those established by the American Society for Testing and Materials (ASTM), Society of Automotive Engineers (SAE), and/or Fed. Test Method Standard #601. Any deviations from these tests must be made known and negotiated between the producer and the customer.

CELLULAR RUBBER MATERIALS TESTING

It is advantageous to consumer or customer to acquaint himself with the basic properties of cellular rubber and its ability to conform to certain quality standards. Being somewhat more pliable and more easily compressed, cellular rubber presents certain problems not encountered with solid rubbers. From an inspection and testing standpoint, such characteristics as load deflection, dimensions, etc., must be measured with a great deal of care as the material is easily distorted when measured by normal methods. Whenever possible procedures such as spelled out in ASTM-D-1056 (SAE J-18), should be used to standardize testing and inspection techniques.

It is extremely important that the customer and the manufacturer of cellular products have a clear understanding of specifications, quality requirements and inspection methods which are necessary to insure the material will perform as required in the application.

PERFORMANCE REQUIREMENTS

Rubber products specifications frequently include performance characteristics as well as dimensional limitations and visual criteria. Typical of these requirements are: adhesion, load deflection, flex-life, abrasion, tensile strength, etc. It is extremely important that appropriate test methods and equipment be specified, as well as the desired limits for such characteristics.*

Requirements for product performance may be expressed as minimum or maximum levels, or in terms which define the degree of percentage of assurance that certain parameters will be met. In either case, it is essential that the conditions of test and the degree of assurance required be clearly defined by the specification.

It must be recognized that much performance testing of rubber products is destructive testing. The economics of destructive testing may limit the degree of assurance which can be obtained that all parts contained in a given inspection lot meet the requirements of the specification. From the quality assurance viewpoint, both customer and producer must rely on the application of reliability principles to determine lot acceptability. Reliability is defined as the probability of successful performance under specified conditions of time and use.

*Reference — Federal Test Method Standard No. 601. Applicable A.S.T.M. standards.

CLASSIFICATION OF DEFECTS

What Constitutes A Defect?

A defect may be defined as a product characteristic which does not conform to the specification for that characteristic. A defective is defined as a complete part or assembly which does not conform to specification, either entirely or in part. Chapters 1, 2, 3, and 4 provide a convenient and readily understandable procedure for specifying quality requirements.

For the most efficient sampling inspections results, defects must be classified on the basis of the effect of each on the intended use of the product. It is recommended that defects be classed in one of these groups which will be defined as follows:

CRITICAL
Those defects which judgment and experience indicate *will* result in failure or malfunction of the product, or which *may* affect the safety of the end use product.

MAJOR
Those defects which *may* result in malfunction or shortened service life of the product, but not affecting safety.

MINOR
Those defects which may make the product less desirable from an appearance or sales standpoint, but which will not affect the life or service of the product.

For certain special products, it may be desirable to add to the above classifications.

QUALITY ASSURANCE PROGRAMS

Prior to the use of any Quality Assurance Program, it is necessary for both customer and producer to have a clear understanding of both the physical characteristics of the product and the quality level required. In addition, consideration must be given to the effectiveness of various forms of inspection such as sampling, 100% screening, etc.

Only when 100% of the units in a lot are inspected for 100% of the quality characteristics of each unit and when this inspection is 100% effective, is "perfect" quality ever attainable. An analysis of such a program establishes the fact that 100% inspection would be:

A. Expensive.
B. Grossly inefficient.
C. Less than 100% effective.
D. Indicative that the risk involved in rejection of good product and acceptance of bad product would vary tremendously, depending on inspector efficiency, and these risks will remain unknown.

The assurance of quality may best be realized through the application of sampling techniques. These techniques have the following advantages as opposed to 100% inspection:

A. The risks in acceptance or rejection are known.
B. Quantitative measurements are known.
C. Optimum inspection efficiencies are achieved.
D. Randomly selected samples from a lot will reflect the quality of the entire lot and serve as an adjunct to process controls.

QUALITY LEVELS, INSPECTION PLANS, AND SAMPLING TABLES

There are at present two basic approaches to evaluation of quality levels in a given production lot or shipment. One approach is through the use of standard sampling tables such as contained in MIL. STD. 105-D. With these tables, the customer specifies a desired quality level (A.Q.L.) and the inspector selects the appropriate sampling plan (based upon the number of units in the inspection lot) designed to assure the specified level.

This method has the advantages of ease of administration, known risks of acceptance of poor quality, uniformity of protection, and economic factors can be easily evaluated. The following Table 46 is recommended for application to all R.M.A. characteristics and tolerance tables included in the technical portions of the Handbook. The customer need only specify the appropriate code designation. The use of this and similar tables is more clearly explained in MIL. STD. 105-D.

Table 46

		RMA DRAWING DESIGNATION						
		Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7
		Acceptable Quality Levels						
Lot Size	**Sample Size**	**.25 Re.**	**.40 Re.**	**.65 Re.**	**1.0 Re.**	**1.5 Re.**	**2.5 Re.**	**4.0 Re.**
0 - 25	5	↓	↓	↓	↓	↓	↓	1
26 - 50	8	↓	↓	↓	↓	↓	1	↓
51 - 90	13	↓	↓	↓	↓	1	↓	↓
91 - 150	20	↓	↓	↓	1	↓	↓	2
151 - 280	32	↓	↓	1	↓	↓	2	3
281 - 500	50	↓	1	↓	↓	2	3	4
501 - 1,200	80	1	↓	↓	2	3	4	6
1,201 - 3,200	125	↓	↓	2	3	4	6	9
3,201 - 10,000	200	↓	2	3	4	6	9	13
10,000 - plus	315	2	3	4	6	9	13	19
Re. — Rejection Number								

A second approach to Lot-Quality evaluation involves the use of sampling tables in which the lot size-sample ratio varies, but the Rejection Number is always one (1). These plans are easy to administer and they usually — but not always — provide a high quality level. Their main problem (if it can be so described) is that the A.Q.L. value obtained varies with the lot size, as does the consumer's risk of accepting undesirable material. Such plans may offer an illusion of a high degree of quality without, in fact, providing the desired quality level. When the situation warrants the use of such a program, the following Table 47 is recommended.

Table 47

	RMA DRAWING DESIGNATION							
	Z 1		Z 2		Z 3		Z 4	
Lot Size	**Sample Size**	**AQL**	**Sample Size**	**AQL**	**Sample Size**	**AQL**	**Sample Size**	**AQL**
1 - 150	15	0.32	30	0.17	75	0.06	100	—
151 - 500	30	0.17	50	0.10	115	0.043	150	0.033
501 - 8,000	50	0.10	150	0.033	300	0.016	300	0.016
8,001 - plus	115	0.043	300	0.016	500	0.01	500	0.01

No defectives allowed. Rejection number is always one (1).

DOCUMENTATION, LOT CONTROL, AND CERTIFICATION

The trend toward tighter quality requirements, and the need for evidence which can be presented in litigation resulting from damage suits, has caused many manufacturers to require documentation of the results of tests and inspections by their suppliers. Such documentation can be provided by most rubber manufacturers; the degree of documentation required will depend upon the stringency of the requirements placed on the end product.

The type of documentation maintained on file by most rubber manufacturers is as follows:

A. Certification and/or tests and inspections on incoming raw materials and components.

B. Results of control tests on uncured compound.

C. Results of final quality assurance inspections and tests on samples taken from the outgoing product.

It is usually more economical for a rubber manufacturer to maintain documentation in his plant, for inspection by vendor inspection teams of his customer. It is, however possible to furnish evidence of tests and inspections in the form of certifications according to the classes indicated in Table 48. Such certifications are intended to ensure that duplication of inspection effort is prevented, and that the purchaser is assured that the product received is as ordered. However, written quality certifications are costly to prepare, and are therefore recommended only when a high degree of confidence is necessary and/or when destructive or special testing is required. Further, it is important to realize that no sampling plan or inspection system is foolproof, and even the most rigid certification, although made on the best information available, is not a 100% guarantee of 100% compliance.

Table 48

CERTIFICATION CLASSES

Drawing Designation	Description
X1*	Materials to be shipped are controlled in homogeneous lots through the rubber manufacturer's process. A written and signed certification is issued with each shipment which presents all pertinent lot test data and results.
X2*	Same as Class 1 except lot test data is maintained on file by the rubber manufacturer and referenced by number on the certification.
X3	Samples are drawn from materials ready for shipment, produced from an essentially uniform process. A written and signed certification is issued with each shipment which presents all pertinent test data and results.
X4	Same as Class 3 except test data is maintained on file by the rubber manufacturer and referenced by number on the certification.
X5	A written and signed certification is issued with each shipment, indicating that the proper material was used to meet drawings and specifications.
X6	A written and signed certification is issued on a periodic basis (monthly, quarterly, semi-annually, etc.) with supporting test data.
X7	A written and signed certification is issued once per contract with supporting test data.
X8	Special certification is required, and customer's format must be used.
X9	No written certification is required.

*Size or other definition of lot is to be established between the customer and the supplier prior to manufacture.

VENDOR RESPONSIBILITIES

For SAFETY AND HIGH WARRANTY ITEMS, the vendor should maintain an effective quality system which satisfies these requirements:

Capability of clearly understanding the purchase order requirements, including all dimensions, chemical, physical, and test specifications.

Capability for measuring and controlling all parts and processes to specification.

Machine and process capability to produce to specification including any necessary process controls to assure conformance throughout the contract period.

Conduct an outgoing audit after final inspection.

Maintain a system for immediate investigation and correction of quality deficiencies.

Control procedures in effect covering the following items:

A. Incoming Quality
B. In-Process Quality
C. Final Inspection
D. Outgoing Quality
E. Change Controls
F. Equipment Capability
G. Corrective Action
H. Gauge Control
I. Disposition of Non-Conforming Material
J. Documentation of Conformance
K. Testing

For OTHER THAN SAFETY RELATED AND HIGH WARRANTY ITEMS, the source must be concerned with the following:

- Be able to satisfy "reasonable care" interpretations by documentation.
- Be able to provide inspection results and certification for specified dimensional requirements.
- Be able to provide periodic certifications and test results for specified test requirements.

DISPOSITION OF RETURNED GOODS

A non-conforming part is one in which one or more characteristics do not conform to the requirements of the specification drawings, or other applicable product description.

The matter of returning non-conforming merchandise and/or customer claims generally is a subject for negotiation between the individual manufacturer and customer.

It is recommended that in the event a question arises concerning product conformance, the customer should provide the supplier with information describing the type and degree (percentage) of non-conformance. If at all possible, samples illustrating the problem should be sent to the supplier.

Notification of non-conforming material to be returned should be given within a reasonable time following delivery.

STATISTICAL PROCESS CONTROL — S.P.C.

Statistical Process Control, S.P.C., a system for defect prevention, is being widely promoted in the U.S. — particularly by the automotive manufacturers. Essentially it is a system in which all the steps in a manufacturing process are monitored. Tests are made and recorded on a statistical basis so that trend and variations are known as they happen. With this technique, corrections to the process are supposed to be made before the process is out of control and before out of specification product is produced.

The system does require developing the necessary instrumentation, tests, and control limits for all of the various variables in the manufacturing process (materials, times, temperatures, pressures, speeds, etc., etc.) that can affect any of the required properties of the finished product.

For those who may be interested or who must begin practicing S.P.C., the following references are recommended:

1. Ford Motor Co., *Continuing Process Control*, Statistical Methods Office, July, 1983.
2. General Motors Corp., *General Motors Statistical Process Control Manual,* Quality & Reliability Office, August, 1984.
3. Ott, Ellis R., *Process Quality Control*, McGraw Hill. New York 1975.

GLOSSARY OF TERMS

Acceptance—The act of an authorized representative of the purchaser by which the purchaser assumes for himself, or as agent of another, ownership of existing and identified supplies tendered, or approves specific services required, as partial or complete performance of the contract on the part of the contractor.

Acceptance Number—A number used in connection with a sampling plan such that if the number of non-conforming test units in the sample taken from the lot is less than or equal to this number, the lot should be accepted.

Applied Skin—A thin surface of elastomeric material.

AQL—(Acceptance Quality Level)—Together with a lot size/ sample size designation is sometimes used for indexing a sampling plan. AQL shall not imply that a supplier has the right to supply knowingly any defective unit of product.

Autoclave—A pressure vessel into which materials or articles can be placed and exposed to steam under pressure. It is commonly used for vulcanization.

Bench March—Marks of known separation applied to a specimen and used to measure strain.

Blister—A cavity or sac that deforms the surface of a material.

Bulk Density—The weight in air of a unit volume of material including both permeable and impermeable voids normal to the material.

Cell—A single small cavity surrounded partially or completely by walls.

Cellular Material—A generic term for materials containing many cells (either open, closed, or both) dispersed throughout the mass.

Cellular Rubbers—Cellular rubber is a cellular material made of rubber. Cellular rubber products all contain cells or small hollow receptacles. The cells may either be open or interconnecting or closed and not interconnecting.

Closed Cell—A cell totally enclosed by its walls and hence not interconnecting with other cells.

Collapse—Inadvertant densification of a cellular material during its manufacture resulting from breakdown of its cellular structure.

Compound—An intimate admixture of a polymer with all the ingredients necessary for the finished article.

Compression Set—The residual deformation after removal of the force which has subjected the specimen to compression.

Cored Cellular Material—Cellular material containing a multiplicity of holes (usually, but not necessarily, cylindrical, in shape) molded or cut into the material in some pattern normally perpendicular to the largest surface, and extending part or all the way through the piece.

Cure—The act of vulcanization. See Vulcanization.

Cut—The distance between cuts or parallel faces of articles produced by repetitive slicing or cutting of long preshaped rods or tubes such as lathe cut washers.

Decay—Internal friction in any free vibratory system will cause the motion to gradually decrease to the vanishing point. This decrease is frequently called "Decay".

Expanded Rubber—Cellular rubber having closed cells made from a solid rubber compound.

Fissure—A split or crack in a cellular material.

Gasket (Mechanical)—A deformable material clamped between essentially stationary faces to prevent the passage of matter through an opening or joint.

Grain—The uni-directional orientation of rubber or filler particles resulting in anisotropy of a rubber compound.

Inspection—The examination and testing of supplies or services (including, when appropriate, raw materials, components, and intermediate assemblies) to determine whether they conform to contract requirements.

Inspection By Attributes—Inspection whereby either the unit of product is classified simply as conforming or non-conforming, or the number of departures from requirements is counted and recorded with respect to a given requirement or set of requirements.

Inspection By Variables—Inspection wherein a specified quality characteristic on a unit of product is measured on a continuous scale, such as pounds, inches, feet per second, etc., and a measurement is recorded.

IRHD (International Rubber Hardness)—For complete definition see ASTM D 1415-68 Standard Method of Test for International Hardness of Vulcanized Natural and Synthetic Rubbers.

Lot (Inspection)—A specific quantity of similar material, or a collection of similar units, offered for inspection and acceptance at one time. A lot is either accepted or rejected as a whole on the basis of examination and/or test carried out on a portion of the lot.

Normal Extrusion—An extrusion that generally requires only extruding, curing and cutting to length without additional shaping.

Open Cell—A cell not totally enclosed by its walls and hence interconnecting with other cells.

Piece—The portion of the sample that is prepared for testing.

Post Cure—A second cure that is sometimes given to products after an original shaping or preforming partial cure.

Preferred Numbers—Preferred numbers are the conventionally rounded off term values or geometric series, including the integral powers of 10 and having as ratios the following factors:

$\sqrt[5]{10}$ $\sqrt[10]{10}$ $\sqrt[20]{10}$ $\sqrt[40]{10}$ $\sqrt[80]{10}$

Source: International Standards Organization (ISO) Recommendation R-3, Preferred Numbers.

Rebound—Rebound is a measure of the resilience, usually as the percentage of vertical return of a body which has fallen and bounced.

Rejection Number—A number used in connection with a sampling plan such that if the number of non-conforming units in the sample taken from the lot is equal to or greater than this number, the lot should be rejected.

Resonance—In forced vibration systems resonance exists when the exciting frequency exactly equals the natural frequency of the spring (rubber body) and mass system.

Rubber—A material that is capable of recovering from large deformations quickly and forcibly, and can be, or already is, modified to a state in which it is essentially insoluble (but can swell) in boiling solvent, such as benzene, methyl ethyl ketone, and ethanol-toluene azeotrope.

A rubber in its modified state, free of diluents, retracts within 1 min. to less than 1.5 times its original length after being stretched at room temperature (20 to 27C) to twice its length and held for 1 min. before release.

Rubber Latex—Colloidal aqueous emulsion of an elastomer.

Sample—A unit, collection of units, or a section of a unit taken from a sampling lot.

Sample (Inspection)—The number of units taken from a lot for the purpose of examination or test.

Sampling Plan—A procedure which specifies the number of units of product from a lot which are to be inspected, and the criterion for acceptability of the lot.

Skin—A relatively dense layer at the surface of a cellular material.

Spring Rate—Spring rate is the ratio of the stress (force) to the strain (deflection).

Sponge Rubber—Cellular rubber consisting predominantly of open cells made from a solid rubber compound.

Swelling—The increase in volume or linear dimensions of a specimen immersed in a liquid or exposed to a vapor.

Tear Strength—The maximum load required to tear apart a specified specimen, the load acting substantially parallel to the major axis of the test specimen.

Tensile Strength—The maximum tensile stress applied during stretching a specimen to rupture.

Tensile Stress—The applied force per unit of original cross-sectional area of a specimen.

Tensile Stress At Given Elongation—The tensile stress required to stretch a uniform section of a specimen to a given elongation.

Tension Set—The extension remaining after a specimen has been stretched and allowed to retract.

Testing—An element of inspection and generally denotes the determination by technical means of the properties or elements of supplies, or components thereof, including functional operation, and involves the application of established scientific principles, procedures, and equipment.

Ultimate Elongation—The maximum elongation prior to rupture.

Void—A cavity unintentionally formed in a cellular material and substantially larger than the characteristic individual cells.

Vulcanization—An irreversible process during which a rubber compound through a change in its chemical structure (for example, cross-linking), becomes less plastic and more resistant to swelling by organic liquids and elastic properties are conferred, improved, or extended over a greater range of temperature.

Waiver Request—A formal document submitted by a contractor to a purchaser for the purpose of requesting acceptance of the designated non-conforming supplies or services, or, for requesting temporary relief from a technical requirement of the contract.

Water Absorption—The increase in weight and volume after immersion in water.

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