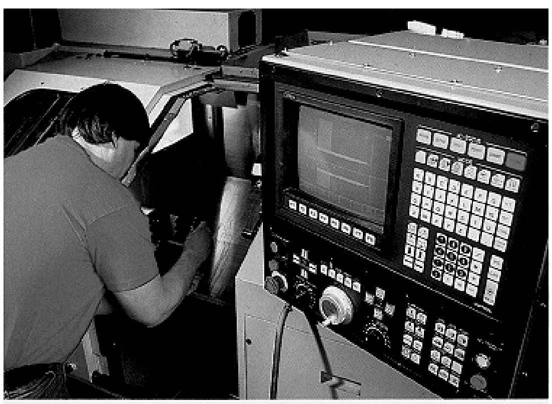
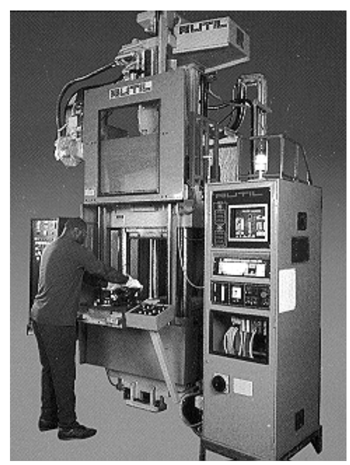
Chapter VI-B.

Setting Specific Properties for Products to Use as Design Guides



Completely computer controlled metal manufacturing lathe.

Computer Disks to choose correct Compound



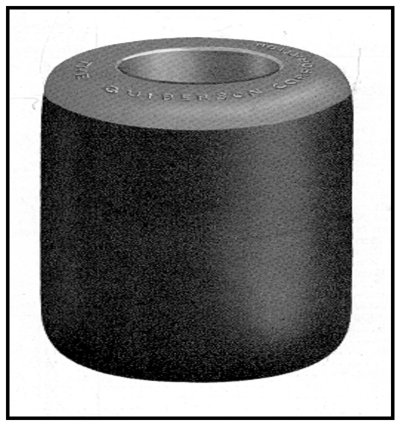
Complete Computer Controlled Injection Molding

HOW TO SET SPECIFIC PROPERTIES

In the design of any product, one of the first steps is to know what is expected of the product in performance and under what conditions it will be expected to perform. With rubber mechanical goods for the oil field this becomes increasingly difficult because the performance conditions from well to well are so varied and the product for the most part is used in a location where it cannot be observed.

It is always the duty of the rubber design engineer to determine what properties are the most important to design toward. The final product will be one of compromise for not all properties complement each other. Once it is determined which properties are the most important the design engineer must determine the nearest environmental conditions to be expected for product use.

The best means to explain the above process is to give examples of products and how most conditions can be met. The most difficult product for which to design a formulation to give proper operation in the oil field has been the stretch on drill pipe protector. The first step is to make a listing of all the properties that is felt may be called upon.



(1) High tensile strength.
(2) High abrasion resistance.
(3) High oil resistance.
(4) High heat resistance.
(5) High cold resistance.
(6) High elongation.
(7) High resistance to set.
(8) High resistance to gas permeation.

A stretch on drill pipe protector must perform at the extreme ends of the temperature scale. It must be capable of being installed in cold weather (-40^{O} - 50^{O} F) and then must withstand high temperature down hole (300^{O} - 350^{O} F). The protector must not swell and reduce the annular area between drill pipe and casing and it must not move once it has been put into place. It must be stretched from 100 to 200% when installed and must immediately snap back to its original size and grip the O.D. of the pipe. Of all the properties needed, which ones are the most important?

As has been stated previously, most formulations to meet oil field specifications are extreme compromises. Actually, those properties listed above are just a starting point. In the instance of the drill pipe protector, the most important property of all does not appear in the initial list. This property is one not

normally considered and is commonly referred to as the "Joule effect". Essentially, this means that rubber when submitted to heat, at the same time it is under tension, will contract. This phenomenon has caused many an "O" Ring to fail prematurely and has a like record with drill pipe protectors. To note this reaction a simple test can be devised. Take a large rubber band and hang one end on a stand. Weight the other end until the band stretches at least two inches. Hold a hot material (such as a lighted match) close to the band without touching. It will then be noted that the weight will be lifted as the band contracts.

We now know that we may design a compromised compound from the original list and not have a good drill pipe protector formulation until we have applied some means of design verification. It is much better that this work be done in the laboratory where sample protectors may be made from different formulations, installed on pipe of the correct O.D. and then immersed in a hot oil bath of the proper temperature. Any failure would be immediate and the rubber design engineer would be able to make adjustments. This is where product quality and reliability must begin. Also, with drill pipe protectors being used down hole, the design must be pointed in this direction.

Another widely used product in the oil field is the swab cup. This product comes in many styles depending upon the design of the supplier and the use for which it is intended. A listing of the most important design concepts show several that coincide with those of the drill pipe protector, but again the rubber design engineer must be proficient in their approach to the product. They must have a compound that will have:

(1) High tensile strength.
(2) High abrasion resistance.
(3) Moderate temperature resistance.
(4) Moderate oil resistance.
(5) High resilience -- Low set (fast recovery).
(6) Excellent adhesion to metal.

Since the swab cup is used as an in and out product it cannot be wholly designed for down hole or surface use, but must have qualities of both. The three most important factors involved in swab cup design are resilience, abrasion resistance and adhesion to metal.

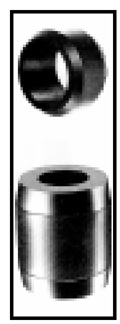
Good adhesion is a must for in many instances some metal reinforcement is held in place solely by the adhesion to the rubber compound. A loss of the reinforcing metal could cause costly delays and in some instances a complete loss of the well. In other cases where no reinforcement is used, the rubber is bonded to a metal sleeve. An excellent bond is needed here or the rubber may be lost on the first run. This can cause costly delays if the rubber hangs up in pumps or seals other well openings.

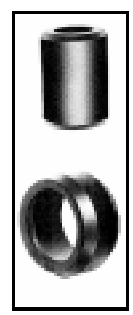
Adhesion of rubber to metal is most difficult to check non-destructively and the rubber design engineer must be very careful of quality control and product reproducibility and reliability in dealing with adhesion to metal.

Resilience is a property that is often overlooked in the proper design of an oil field product. In swab cups it is most important, especially in its effect upon the cup returning to its normal shape after being flexed. When a swab cup is pulled from a well under load, it will expand and contract as it passes through each coupling. In many cups the metal reinforcing acts as a guide through the couplings, but the rubber must also snap back immediately or it will be cut at each coupling. Thus, resilience is important to help swab cups up the hole without premature failure caused by cutting from the couplings. Since the swab cup is an in and out product, abrasion resistance and resilience are more important to design than are oil and heat resistance. The swab cup will normally fail in abrasion or cutting long before oil or heat will cause any degradation leading to failure.

A third difficult product design category is the various types of packing elements. A packing element may be used on a permanent set drillable or retrievable packer. There is a difference between the design of the two, but both are used down hole only and are also used to pack off the annular area between the O.D. of tubing and I.D. of the casing and retain the pressure of one or more formations. A listing of packer element properties are as follows:

(1) Low compression set.
(2) High tensile strength.
(3) High heat resistance.
(4) High resistance to oil swell.
(5) High modulus (resistance to cold flow).
(6) High compressive modulus.





Due to the type service, the depth of the packer setting, the temperature involved and the pressures to retain, there are various levels of design for a packer element. In all instances it is most important to maintain a low compression set with high compressive modulous and high heat resistance.

How many times has it been heard through the years that the rubber in a packer element has vulcanized to the casing? Actually, the rubber compound was poorly designed and when the element was put under pressure to seal the annular area and was held in this position for a long period of time at temperatures of 250^{O} F and up, the vulcanization process continued and the element was reformed. As a result of poor

compression set (the lack of return to original shape after pressure removed), the packing element made it impossible to remove the packer. In some instances strings of tubing have been pulled apart due to strain on the tubing string when trying to move a packer. Vulcanization to or bonding to the casing is practically impossible because unvulcanized rubber must have a clean oil free surface with an adhesive added to bond to metal during the vulcanization process. These conditions do not exist down hole.

In the instance of packer rubbers, the depth at which the packer is to be set becomes a vital point. If the rubber element is not properly matched to the amount of weight or pressure available to set the packer, the packing element will not seat properly and pressure bypass may be encountered. The compression modulus at the temperature and depth of packer set must be in the proper range to accomplish the desired pack-off. It is difficult to accomplish this result in a one piece packer rubber and the multiple ring type with a variation of compression modulii with the compounds with the highest values in elements toward the outside and the lowest in the middle is much better to cover a broader range of requirements. By this means shallow and deep holes may be packed off equally as well with the same rubber elements by varying the compression modulii properties in the correct ratios.

In conclusion two additional products should be considered before closing this phase of discussion. These two products are used at the surface. The first is used as a well seal and stripping element and the other is used basically as a stripping element. The former is commonly called a tubing stripper and the later is called a drill pipe wiper. Both products, although used in different oil field applications, are essential products and do perform similar functions.

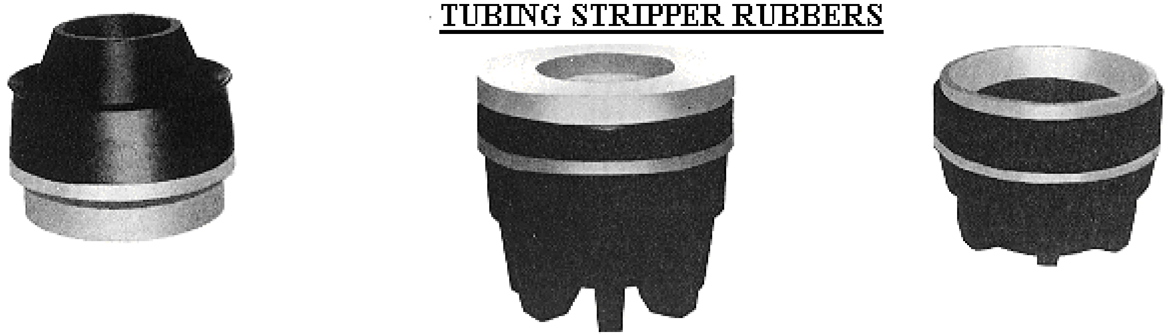
They are considered surface products and more emphasis is placed on the design for high resilience and abrasion resistance than for heat and oil resistance and high physical properties. With the tubing stripper rubber, a dual function is performed. The rubber must seal in the well pressures and also strip the well fluids back into the well when the tubing is pulled. The drill pipe wiper must strip the well fluids back into the well as the drill pipe is removed and also keep junk from falling in the hole. Both products will wear out due to cutting or abrasion loss long before oil or heat could produce a failure.

The tubing stripper is used basically in production operations and the drill pipe wiper in drilling operations. Both products must expand under a low force and must close again quickly to establish a seal around tubing or drill pipe. Resistance to cutting and abrasion are a must in both instances. Tubing strippers must have an excellent affinity for metal adhesion. Both drill pipe wipers and tubing strippers must be made from high resilience low modulus compounds for they must effect a tight seal on irregular and rough surfaces without abrading away due to excessive rigidity.

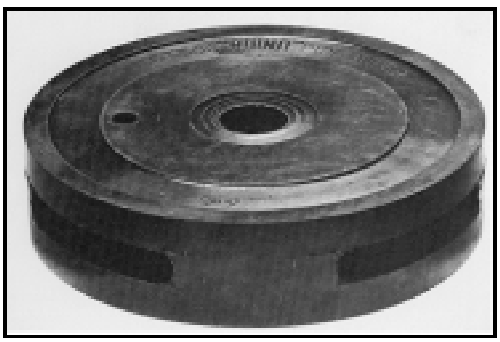
It is realized that the noted examples are a range of products that have been in use for a multitude of years. Naturally, one would think that expertise has been developed to the point on these examples that an acceptable product can be made by any of the available vendors. This is true only if the customer demands it by his setting of specifications for products to be used in and with his tools.

An attempt has been made to point out some of the differences between the requirements for surface and down hole use. There are many more considerations than have been shown, but it is felt an awareness must be promoted to enable the oil tool design engineer to set specifications for the rubber products based upon use and location of a particular tool.

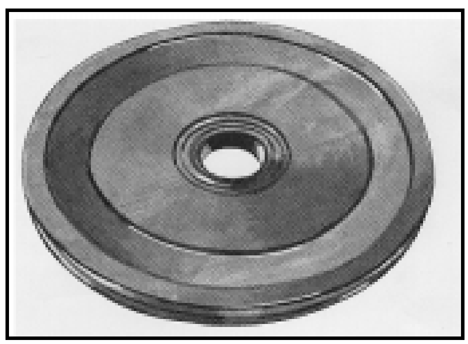
TUBING STRIPPER RUBBERS



PIPE WIPERS



DOUBLE



SINGLE

QUESTIONNAIRE HEADING TO GOOD PRODUCT DESIGN

In all of the preceding discussion, it has been assumed the oil tool design engineer has a complete knowledge of rubber, rubber compounding and rubber processing. This is not necessarily the case, but they can be given an additional aid to further their abilities in this direction.

As an aid it is proposed that a simple series of questions can be set up by the rubber design engineer to be answered by the oil tool engineer. This will help pave the way for product production that will satisfy performance needs and will be profitable for the vendor to produce. These questions should be simple in scope and should be easily answerable by the oil tool engineer. The answers definitely will be the first guide to the rubber design engineer in the task to find a material and mold design to give a workable product.

The questionnaire should begin with notes of general information. These will include such things as part description, part number, type equipment use, function (as to static or reciprocating, etc.), number of uses, service life expected, location of use (surface, down hole, etc.), condition of hole to be used in and pressures to be contacted.

The next series of questions should be categorical design characteristics that should be met by the rubber compound. These properties should be chosen by the rubber design engineer very carefully and should be thoroughly explained in order for the oil tool engineer to understand the need for an accurate estimate of each property's effect on the product.

The third series of questions will begin the actual design sequence. These properties will deal with specifics. They will include environmental conditions such as temperature requirements with an estimate of maximum and minimum, whether the temperature is constant or cyclic. Another environmental condition might be an evaluation in certain fluids or gases. Here the questions would cover what fluid or gas might be contacted, what the permissable volume change might be, what blistering would

be acceptable and what might be the length of service required and what condition must be maintained.

The last section would cover an estimate of ranges of desired values that the oil tool engineer is setting for his product in the previous sections. It must be kept in mind that most rubber compounds are made from a compromise mixture and not all values can be at extremes. In choosing specific value ranges the oil tool engineer has taken this fact into account, but they have also given the rubber engineer a series of check points to meet.

To close this section, it would be best to give a short one question example of all parts of the proposed Design Questionnaire.

OIL TOOL RUBBER PRODUCTS

DESIGN DATA CHECK LIST

GENERAL INFORMATION

Part Description:____

Part or Drawing No.: _____________________________________

Function of Part:____

____

____

CATEGORICAL RUBBER DESIGN INFORMATION

Resiliency: **Expressed by the ratio of energy given up on deformation to the energy required to produce the deformation. It may be expressed as amount of rebound of a free falling weight when it has fallen against the rubber sample and expressed in percent.**

Resiliency: __________%

ACTUAL RUBBER DESIGN INFORMATION

TENSILE PROPERTIES REQUIRED

Is part in Tension: __________ __________psi @ Room Temperature.

Is part in Tension during use: __________psi @ _____________ F.

As a result of: _______________% elongation

Tensile Stress: __________ ___________% @ Room Temperature.

Compressive Stress: __________ __________% @ ___________ F.

Elongation: __________%

Compression: _________%

I.D. __________________% O.D. __________________%

SUGGESTED PROPERTY RANGES

VALUES TO BE INSERTED IN FIRST

SECTIONS OF THIS QUESTIONNAIRE

Tensile Strength

In psi 500-1000; 1000-2000; 2000-3000; 3000-4000
In psi @ 50% Elongation 50-150; 150-300; 300-700;700-1200

1200-2000

In psi @ 100% Elongation 300-600; 600-1000; 1000-1500;
1500-2000; 2000-3000

In psi @ 300% Elongation 1000-1500; 1500-2000; 2000-2500;
2500-3000

This has just been an abbreviated look at a suggested plan for posing questions to the oil tool engineer with help in answering. This form can be expanded to cover all of the capabilities of the rubber vendor's R and D laboratory and the specific needs of the oil tool manufacturer.

At this point, the oil tool engineer starts to become in complete control of the product. If they continue to work with the rubber vendor in this manner, they will improve product performance and will demand that quality controls insure duplication of the product from production run to production run.

COMPLETE QUESTIONNAIRE
PRODUCT DESIGN DATA

This product design data presentation Is designed to aid both customers and technical staff to select or design materials to assure satisfactory product performance. All information supplied will be held confidential.

All values are to be obtained in accordance with ASTM test procedures

To facilitate answering the questions contained in this data presentation,, there has been appended a tabulation of ranges of physical properties normally obtainable in rubber compounds.

Information contained in this questionnaire is proprietary information of MP Industries Inc. and the questionnaire and information are confidential.

Customer:
Address:

Requested By

GENERAL INFORMATION

Part Description:____

Part or Print Number:____

Equipment Used On:____

Function of Part:____

Static Seal____
Reciprocating Seal_________Length of Stroke________Cycles/min._____
Rotating Seal_______R.P.M. of Shaft________Feet/min.________________

Is Part to be re-used:______________Number of Uses:____________________

Service life per use cycle:________Mos._________Days______________Years

Will part be stored between uses:____________ Yes_______________No.

Surface to be sealed:____
Cased Hole:____
Open Hole:____
Machined Surface:_____________Finish:________________RMS. MAX. -
CAST Surface:_________________Type Casting:_____________________
Pressures to be sealed:___________________Static_______________Pulsating
_______psi. Min._______________psi Max._____________psi. Differential

PRELIMINARY RUBBER DESIGN INFORMATION

Where the following properties of rubber are involved in product performance, information is necessary for the rubber technician to be used in compound design and should be considered by the Engineer in Product Design.

SHAPE FACTOR

For parts having parallel loading faces and sides normal to these faces, shape factor is the ratio of the area of one load face to the areas free to bulge or expand laterally. A cylinder where diameter equal height has a shape factor of 0.25. Higher Shape Factors require higher compressive stresses to achieve a given deformation. Higher stresses result in lower recovery from compression and can be a measurable factor in avoiding creep that can result in "Creep to Failure" stresses.

Shape Factor:____

CREEP

Creep is the additional deformation occurring with lapse of time in a body under stress. In rubber it is present at any stress level. It can be minimized by compounding and by low working stresses particularly at higher temperatures. It can most usefully be expressed in percentage of original deformation.

Creep:____%

RESILIENCY

Resiliency is the ratio of energy given up on deformation to the energy required to produce that deformation. For purposes of this data presentation it should be expressed as percentage of

rebound of a free falling weight against the rubber sample. Ranges of re-siliency are given in the table of suggested Ranges of Obtainable Physical Properties.

Resiliency:______________________________%

HYSTERISIS

This property is defined as percent loss of energy per cycle of deformation, or 100% minus resiliency percentage. For purposes of this data presentation it can also be expressed as a percentage better than one of our other compounds.

Hysterisis________________%

___________ % Better Than Compound__________________

ABRASION RESISTANCE

This is a hard to define property of rubber in as much as it is a purely relative term meaning that a material having "High Abrasion Resistance" suffers little loss of volume from abrasive action. It is related to stiffness, thermal stability and the material's resistance to cutting and tearing. Being a relative term it is best expressed as a percentage better than another of our compounds.

Abrasion Resistance_______________% Better
Than Compound:__________________________

RUBBER DESIGN INFORMATION

TEMPERATURE REQUIREMENTS

Operating Temperatures: __________________Max.______________Min.

___________________Constant

_______________ Cyclic_________Time/Cycle

PERMISSABLE VOLUME CHANGE

Fluid or Gas to be Sealed:___ +______% in______________________@ Room Temp.

___________________________ +______% in________________________@_________°F

___________________________ -______% in________________________@ Room Temp.

___________________________ -______% in________________________@_________°F

Gas Pressure____________psi

Is Gas Present in Fluid:____

If So What Percentage_____%

If Service is Gas or Gas in Fluid to What Extent is Blistering Allowed:

Must Not Blister:__________________________________

Small Blisters OK:________________________________

Large Blisters OK:________________________________

Pressure Drop OK:________________________________

<u>TENSILE PROPERTIES REQUIRED</u>

<u>TENSILE</u>

Is Part Used In Tension:____ _______________________________psi @ Room Temp.

Is Part Elongated In Use:____ _______________________________psi @_________°F

As A Result Of: ____________ ELONGATION

Tensile Stress:_______ _______________________________% @ Room Temp.

Compressive Stress:____ _______________________________% @__________°F

Elongation Of:________

I.D.______% O.D.______%

<u>TENSILE MODULUS</u>

Force Required to Elongate ______psi @_____________% Elong @ Room Temp.

Part:_________________psi **______psi @_____________% Elong @_________°F**

______psi @_____________% Elong @ Room Temp.

______psi @_____________% Elong @_________°F

TEAR (GRAVES)

Will Sides of Groove or Support Be:

Chamfered: _____in @______° **_____________lbs/in. @ Room Temperature**

Radiused: ______in **_____________lbs/in @ __________°F**

HARDNESS (SHORE A)

Will Load Application Be: **___________ Duro @ Room Temperature**

Slow:____Time To Apply:_____ **___________ Duro @ ____________°F**

Sharp:___________Izod Impact:_______________Ft.Lbs.

COMPRESSIVE PROPERTIES REQUIRED

What Percent Will Part Be Compressed In Use _____%

COMPRESSION SET IN % OF ORIG. DEF.

_________% Dry Heat Aged_____Hrs @____°F.

________% _________Aged____Hrs @____°F.

Load Will Be:

Constant:________________

__________________Cycle

SHEAR STRESS INDEX

Will Part Be Subject To

Deformation Thickness_____@ Room Temp.

Shear: _____________ **Deformation Thickness_____@ ________°F**

Will Shear Be:

Linear:_______

Rotative:_____

Frequent:_____

Occasional:____

Linear Deformation:_____in.

Rubber Thickness:______in.

NOTE: Shear Strain (Modulus) is ratio of deformation to rubber thickness and is theoretically about 1/3 of compressive modulus.

<u>COMPRESSION MODULUS</u>

Part Will Be Deflected _______% **___________Psi @ ____% Def. @ Room Temp.**

Compressive Force Will Be **___________Psi @_____% Def. @_______°F**

____________psi **___________Psi @_____% Def. @_______°F**

Annular Clearance Will Be **___________Psi @_____% Def. @_______°F**

_______in Max.

Will Load Faces Be:

Bonded:______________________

Restrained by Friction:_________

Free To Move Laterally:________

SUGGESTED OBTAINABLE RANGES OF <u>PHYSICAL PROPERTIES</u>

It is suggested that: values stated in the product design data be specified as a range of properties

rather than in absolute values.

ULTIMATE TENSILE

P.S.I.: 500 - 1000; 1000 - 2000; 2000 - 3000; 3000 - 4000

TENSILE MODULUS

P.S.I . @ 50% Elongation: 50 - 150; 150 - 300; 300 - 700; 700 - 1200; 1200 - 2000

100% Elongation: 300 - 600; 600 - 1000; 1000 - 1500; 1500 - 2000; 2000 - 3000

300% Elongation: 1000 - 1500; 1500 - 2000; 2000 - 2500; 2500 - 3000

ELONGATION

Percent: 50 - 100; 100 - 200; 200 - 300; 300 - 400; 400 - 600

TEAR (GRAVES)

LBS/IN 50 - 100; 100 - 200; 200 - 300; 300 - 400; 400 - 600

DUROMETER

SHORE A: 40 - 50; 50 - 60; 60 - 70; 70 - 80; 80 - 90; 90 - 100

COMPRESSION SET

% MAXIMUM of Original Deflection (22 Hours)

@ 158° F. 0 - 15; 15 - 25; 25 - 35; 35 - 50; 50 - 70; 70 - 90

@ 212°F. 25 - 35; 35 - 50; 50 - 65; 65 - 75; 75 - 90

@ 300°F. 35 - 55; 55 - 75; 75 - 100

@ 350°F. 50 - 70; 70 - 80; 80 - 100

COMPRESSION MODULUS

P.S.I. @ 30% Compression

Room Temp: 200 - 400; 400 - 600; 600 - 800; 800 - 1000; 1000 - 1200

150°F) Lower values will be obtained at these temperatures
300°F)
350°F) Specifications should anticipate this loss

VOLUME CHANGE

ASTM #1 AND ASTM #3 OILS (SPECIFY)

Values to be given as both % min. and % max. permissible

Room Temperature: 0 - 10; 10 - 15; 15 - 25; 25 - 50

100°F) Temperature will accelerate chemical attack on compounds
200°F) both volume swell and volume loss. Consideration must be
300°F) given to this when specifying value at operating temperature.

RESILIENCY

Rebound %: 0 - 10; 10 - 20; 20 - 30; 30 - 40; 40 - 50; 50 - 60

Good Character—

like good soup —

is usually homemade.