PLAINTIFF'S EXHIBIT

CT-1445

CERTAIN-TEED PRODUCTS CORPORATION

FOR Ambler Pipe DATE September 16, 1964 FROM Ambler R&D

ATTENTION OF See below SUBJECT Rubber Rings For Use With Asbestos-Cement Pipe

ANSWERING YOURS DICTATED BY C. R. Hutchcroft/mdp CRH

Rubber rings are the seals in our couplings which make it possible to join lengths of pipe together into a usable pipe line. Although Certain-teed Asbestos-Cement Pipe is essentially indestructible when properly laid, a pipe line is no better than its joints. In order to insure joints which will equal the pipe in longevity, the rubber rings used are of the highest quality which can be made for the purpose. Our suppliers have advised that our specifications are the most exacting in their industry.

From time to time, customers and people within our own organization have asked questions about the rubber rings we use. Due to this interest, it was felt that a paper describing these rings, their compounding, manufacture, inspection, and usage would find an interested reception.

Mr. Frank Law, Manager of our Materials Laboratory, prepared a paper entitled "Rubber Rings for Use With Asbestos-Cement Pipe". It is enclosed herewith. We think you will find it both interesting and useful.

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RUBBER RINGS FOR USE WITH ASBESTOS-CEMENT PIPE

1.0 Introduction

Rubber rings have been used in couplings to join asbestos-cement pipe ever since the first asbestos-cement pipe was made by K&M in 1938. Rubber rings have been used as the gasketing material because of ease of assembly, reliability, sealing properties, and reasonable cost. The design of the rubber ring has changed from the round and square types used with malleable iron couplings; the O type simplex rings; to the present day "Fluid-Tite" ring, which is considered superior to any ring used to join any pipe on the market today.

As the asbestos-cement pipe business expanded since 1938 so did the use of rubber rings so that today CPC purchases of rubber rings is in excess of a million dollars. For this reason and also because the joint is the most critical part of the pipe system, much emphasis has been placed on the quality of the rubber rings; an often heard saying is that "the best ring is not good enough", although recently a rubber ring manufacturer was heard to say, "if your pipe is as good as our ring, we can build a pipeline to heaven".

Since rubber rings, and "Fluid-Tite" rings in particular, are so important a part of our business, it might be well to know a little more about them and rubber in general.

2.0 "Fluid-Tite" Rings

A. Use

"Fluid-Tite" rings are used to join CPC asbestos-cement pipe couplings. They must prevent leakage from both the inside out and the outside in.

B. Description

One of the big problems in describing "Fluid-Tite" rings is definitions. A "Fluid-Tite" ring is a gasket; it is also a seal and it can be considered an O ring. A gasket is a packing employed in a joint whose members remain in essentially stationary relationship. A seal is a packing which is self tightening; that is, it requires no manual adjustment--or--a sealing connection, as a water seal. An O ring is a packing ring of round cross section used alone in a groove, it is self tightening. All the above definitions include the word packing and since the ASTM Committee, which has written the specification for

rubber gaskets for use with asbestos-cement pipe -- ASTM D1869-63T, is the packing committee, a definition of packing is included. A packing is a device employed to create a gaseous or liquid seal on joined surfaces such as piping or other vessels on containers. "Fluid-Tite" rings meet parts of all the above definitions. It could be described as a gasket (joint which is stationary) used as a packing (a liquid seal used on piping) seal (requires no manual adjustment) of the O ring type (used in a groove of proper dimensions). In addition to the requirements listed above, it must also be impervious to the material carried in the pipe. In almost all cases water is carried in asbestos-cement pipe; however, the water is not necessarily potable water. It may contain sewage, or as in the oil fields, light hydrocarbons.

The "Fluid-Tite" ring has been especially designed so that it will exert its most effective sealing properties under service conditions.

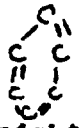
3.0 Rubber

The problem of finding a material that is plentiful, of good quality, reasonable cost, long life, impervious to water and water contaminants, will act as a seal in a confined groove and is self tightening, is formidable. Fortunately there is a material that meets all of the above requirements when properly prepared. This material is rubber. Rubber in this sense is used as a generic term and includes both natural rubber and synthetic rubber.

A. Description

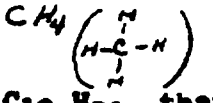
The first question that comes to mind is "What is rubber?" Because of the many types present on the market today, a definition must be all inclusive. The one property that is common to all rubbers is its tremendous elasticity. This property also sets rubber apart from other substances. From the elastic property the word elastomer is derived, therefore rubber is an elastomer. Elasticity is the property that allows a material to be deformed without permanent deformation when the stress is withdrawn; a good example is a rubber band and a piece of tin. Stretch a rubber band and it will return to its original size when the stretch is released; put a dent in a piece of tin, the dent will remain when the object used to make the dent is withdrawn.

The elastic property of rubber is not enough to define it, so more common ground must be found. All rubber contains carbon and hydrogen. This is another clue. It is not enough to have just carbon and hydrogen, they must also be in a certain arrangement. Carbon of itself can be a diamond, graphite, charcoal, coke, or lampblack. Hydrogen is a gas, the lightest substance known. Carbon is the basis for organic chemistry which consists of hundreds of thousands of compounds. A property which carbon has is its ability to combine with itself in either a straight line called a chain; i.e. C-C-C or a circle called cyclic, i.e. --



(C is the chemical symbol for Carbon. H is for Hydrogen).

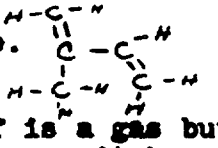
The straight chain series is called aliphatic compounds and the cyclic, aromatic compounds. Rubber is concerned with the straight chain or aliphatic compounds. One of the simplest compounds of straight chain carbon is hydrocarbons, the affinity or carbon for other carbon atoms and hydrogen. The length of the carbon chain and the number of hydrogen atoms tied to the chain determine what properties the compound will have; i.e. CH_4



is methane, a very light explosive gas, while $C_{10}H_{22}$, that is 10 carbons in a straight chain with 22 hydrogen atoms attached to the chain, is kerosene. As the chain increases in length, the compounds become more dense.

Carbon also has the ability to form double or triple bonds with another carbon; for instance, acetylene H-C≡C-H. The double and triple bonds make the carbon atom much more reactive. As is well known, acetylene is highly explosive and burns with tremendous heat. The double and triple bonds are mentioned here for they are important in rubber as will be seen later on.

Rubber contains carbon and hydrogen. The combination of the carbon and hydrogen in the molecule is always the same, the rubber molecule is C_5H_8



The chemical name for this molecule is isoprene.

This molecule taken by itself is a gas but when the molecule is repeated many many times, it becomes rubber. The combination of two or more identical molecules is called a polymer. The formula for rubber is usually written (C_5H_8) 20,000 - this means there are twenty thousand of the isoprene molecules combined to form one molecule of rubber. By varying the length of the chain different properties may be given to the rubber.

The isoprene molecule represents natural rubber. The synthetic rubbers are combinations of polymers with other polymers and/or the replacing of one of the hydrogen atoms with other compounds. For instance, neoprene replaces one hydrogen atom with a chlorine atom in each molecule (neoprene is often called chloroprene). Therefore rubber is a polymer with elastomeric properties. The elastomeric properties are given to the polymer not only by the length of the molecular chain but also by the arrangement of the molecules. The molecules in rubber are in a haphazard arrangement. When they are stretched, they straighten out. When the stretch is released, they return to their original condition. They can be likened to a coiled chain; when it is suspended, each link forms a pattern with the other link in a straight line pattern. When the chain is dropped, the links fall haphazardly. The above explanation on elastomers, polymers, and rubber is over simplified but for the purposes of this discussion is believed to be adequate.

B. History

A brief history of how this all started might be of interest. When the Europeans first explored Central and South America, they noticed that the natives used the exudation of certain trees to make balls which bounced well and also to make a crude water proofing type boot. The natives called this material "cachue". The English scientist Priestly found out it could be used to rub out pencil marks and called it "rubber" which name has been used ever since.

The development of rubber was not advanced for nearly a hundred years after it was first found. The Spanish, who first found it, never did develop it. In the early 1800's Hancock in England and Goodyear in the United States began working with rubber as they felt any material having such unusual properties should be put to practical use. It was flexible, tough, waterproof and impermeable to air. In the beginning many products made with rubber appeared to be excellent when first made; however they did not last long as there were two major troubles. The articles got brittle and stiff in cold weather and soft and sticky in hot weather.

In 1839 Goodyear discovered that when rubber is heated with sulfur, it becomes drastically changed. The strength and elasticity are greatly increased and hot and cold temperatures no longer affect it. There is one story that Goodyear accidentally dropped some sulfur into boiling rubber and discarded the mixture. The following spring he noticed

that the rubber still maintained its original properties even though being exposed to the winter weather. Whether the story is true or not, it has developed into over a billion dollar a year industry.

With the advent of the automobile, the price of rubber skyrocketed and was ruthlessly exploited. At about this time seedlings taken from Brazil to Kew Gardens in London were transplanted in Ceylon and Malaya. The story of the Mutiny On The Bounty is connected with this trip and is true. The great demand for rubber caused a commercial interest in growing the rubber trees. The growth in Ceylon, Malaya, Indonesia and Indo-China was phenomenal and by 1920 produced 90% of the world supply.

At the time Goodyear and Hancock were working on rubber, great strides were made in organic chemistry, including trying to make synthetic rubber. While this was not successful till later, the non hydrocarbon products produced in these efforts found outlets as accelerators, anti-oxidants, plasticizers, etc. until an industry within an industry was developed.

Natural rubber reigned supreme with very little serious attempts to make synthetic rubber. The cost of R&D for synthetic rubbers was high as was the processing. At the same time natural rubber was plentiful and the cost reasonable. The synthetic rubbers gained prominence for two main reasons:

1. Natural rubber is easily attacked by other aliphatic hydrocarbons, kerosene, gasoline and the like. In 1930 Neoprene, Buna N, and Thiokols were produced. These products showed excellent resistance to petroleum oils and solvents and improved resistance to light, heat, and ozone. These products cost more, but the difference in price was made up by their much longer life.

2. The second reason, and the most important one, was World War II. Very early in the war Japan cut off 95% of the world supply of natural rubber. Militarily they had a tremendous advantage as was shown by the Allied Blockade of Germany in World War I. When the nations were preparing for World War II, the necessity of replacing natural rubber was known. A crash program was started under the sponsorship of the U.S. Government. The problem was solved and synthetic rubber was

produced. While in the beginning it was not as good as natural rubber, it was sufficient to do the job. Once the barrier had been cracked, improvements were made rapidly and new polymers were developed.

Today the synthetic polymers amount to 70% of the total rubber usage. The advantages of synthetic rubbers are: More uniform quality, low cost because of large volume, can be compounded for specific properties; i.e. low compression set or ozone resistance. It must be remembered that up to the present time, there has not been a synthetic rubber developed that has <u>all</u> the properties of natural rubber.

In the manufacture of "Fluid-Tite" rings there are three main rubbers that are used: Natural Rubber - NR, Butadiene-Styrene Rubber - SBR, and Butadiene-Acrylonitrile Rubber - NBR (Buna N or Oil Resistant). Each will be discussed separately.

4.0 Natural Rubber - NR

Natural Rubber occurs in the latex of the Hevea Brasiliensis tree. It is contained in tubes which are located directly in the bark of the tree. These tubes spiral left to right as they ascend the tree. The exact function of the latex to the tree is not known. These trees, although originally coming from Brazil, are cultivated almost exclusively in the tropical rain forest regions of all continents. The trees are cultivated in plantations. By cross breeding from the original trees, the yield has been increased from 250 lbs. per year per acre to 1500 lbs. per year per acre with some being as high as 3000 lbs. All seedlings taken from one tree are called clones.

The latex is obtained from the tree by tapping. This is done by making a spiral cut downward in the bark of the tree through the ducts. The latex then is collected in a cup. The latex is collected and sent to a central factory or collecting station. As the latex is being collected, a preservative is added to prevent coagulation. At the factory the latex is strained to remove dirt and bark particles, then coagulated, formed into sheets, washed and hot air dried (with wood smoke in some cases) and packed into bales. The rubber is classified into various types and grades. The type refers to the preparation given to the rubber and the grade to the quality. Only the highest type and grade of natural rubber is used in "Fluid-Tite" ring.

Natural rubber contains small amounts of materials other than the rubber hydrocarbon molecule after it has been processed.

These materials are from the latex and have a pronounced effect on the rubber. These materials include fatty acids, important for vulcanization; natural sterols and esters necessary for protection of the rubber from the air and sunlight; and proteins. The proteins are troublesome. If they are not extracted they are subject to bacterial attack and will eventually destroy the rubber.

The rubber in the uncured state is stisky, has poor strength, fantastic elongation properties, poor resistance to aging, or in other words, the same as Goodyear first found it. The continuity story of natural rubber shall be picked up later, after SBR and NBR rubbers, as the processing in the manufacture of the finished product is the same for all of them.

5.0 Butadiene-Styrene Rubber - SBR

The Butadiene-Styrene Rubber received its first impetus during World War I in Germany when the supply of Natural Rubber was cut off by the Allied Blockade. The first attempts were rather poor and after the war, when natural rubber was plentiful, the development was carried out on a small scale. When World War II loomed on the horizon, the U.S. Government became interested in synthetic rubber and took over plants to produce it. From this came the old term GR-S (Government Rubber - Styrene). The development of this material was so successful that today it comprises approximately 80% of all synthetic rubbers. Its principal advantages are uniformity, low cost, plentiful, and in many cases certain properties can be processed into it.

In an earlier discussion on what is a polymer, it was pointed out that it is the addition of two or more identical molecules. In SBR, the addition is of two polymers to produce co-polymers.

The chief raw materials are butadiene C_4H_6 and styrene $C_6H_5CH=CH_2$. The butadiene is a by-product from petroleum while styrene is obtained from the reaction of benzene and ethylene. Both the butadiene and styrene are polymerized in the same reaction chamber to form a complex molecular co-polymer. The processing and chemistry involved are very complex and beyond the scope of this discussion. An interesting note on SBR is that for years butadiene was polymerized into a rubber as was styrene. Neither was close to giving the properties of natural rubber, however when they are co-polymerized, the co-polymer exhibits many properties superior to natural rubber. SBR rubbers do not have the tackiness that natural rubber has and therefore are harder to process. Since they have less double bonds than

natural rubber, they are not as reactive and have less tendency to overcure. The resilience, tensile and elongation of SBR rubbers are not as good as natural rubber, while the compression set and abrasion resistance can be superior. The amount of butadiene to styrene is important, 70% butadiene to 30% styrene is rubber; reverse the percentages and the material is a dense plastic. The processing will be picked up later.

6.0 Butadiene-Acrylonitrile Rubbers - NBR

These rubbers are commonly called Buna N or Oil Resistant Rubbers. Like SBR, it is a product of co-polymerization, in this case between butadiene C_4H_6 and acrylonitrile (CH_2 CH C ≡ N). The processing is similar to SBR although it is manufactured under 150 psi pressure. The primary function of NBR is its excellent resistance to petroleum oils and solvents. The amount of resistance to petroleum oils and solvents is determined by the amount of acrylonitrile to the amount of butadiene in the co-polymer, the more the acrylonitrile, the greater the oil resistance. In general, the NBR compounds are more resistant to chemical attack than natural rubber or other synthetic rubber. In any case where the chemical resistance of the rubber to a substance is not known, the safest (and most practical) approach is to test it in the laboratory first.

Buna N rubbers have considerably lower tensile strengths and elongations, but better aging properties and compression set characteristics than natural rubber and SBR.

From this point on the processing and compounding of the rubbers is the same, keeping in mind that the processing times and the amounts of the various ingredients may vary.

7.0 Processing

A. Compounding

The raw rubbers cannot be used for useful products. To make them into a useful product is the function of the compounder. The compounder must find out what the end use of the product will be and to what conditions it will be exposed. For instance, if high resistance to petroleum oils is necessary, he would select a stock that has a high acrylonitrile content; or as in the case of "Fluid-Tite" rings, he would select plasticizers that are not soluble in water.

(1) Compounding Ingredients

In the compounding of rubber there are many ingredients used. They will be defined in general terms with few specific references made.

The most important function of "Fluid-Tite" rings is to form a seal so that no water may leak out or in. In addition this seal must be maintained for as long as the pipe lasts (perhaps 100 years or more). Therefore compression set is the most important property in CPC rubber rings, with resistance to compression a close second and aging properties third. The rubbers in their uncured state have extremely poor compression set and no strength in addition to poor aging characteristics. The cured rubbers with no additions have compression sets of approximately 50%, poor aging and very high costs hense the need of additives to the rubber stock. These additives are:

a. Accelerators - These are organic compounds used to speed up the vulcanization or curing process. They are used in addition to sulfur. Using sulfur alone, the curing process would take hours. With the accelerators, the curing process is cut to minutes. Many accelerators are natural fungicides and bacteriacides.

b. Sulfur - Necessary for vulcanization in most compounds. However some compounds use peroxide cures, while some others will use litharge or metallic salts.

c. Plasticizers - Two types.

Chemical Plasticizers - which effect the crude rubber and make them more workable by cutting the chain length. This type of plasticizer has little effect on the vulcanized product.

Physical Plasticizers - which effect both the raw and vulcanized rubber. This type of plasticity lubricates the rubbers so the chains slide past each other. They do not chemically join with the rubber and are not driven out during vulcanization. In the cured rubber they give softer (less hard) and more elastic rubber with reduced strength. With this type of plasticizer, it is most important that the solubility be determined against whatever media the final product is to be used. Another point to

be emphasized with physical plasticizers is that they must be non-toxic. The physical plasticizers are commonly known as softeners. SBR and NBR stocks will use more plasticizers than will natural rubber.

d. Extenders - Are actually physical plasticizers but the main function is to cut the cost of the stock. (Dilute the rubber). These are not used in this sense in "Fluid-Tite" rings.

e. Anti-Oxidants and Anti-Ozinants - In the previous discussion it was pointed out that the double bonds in the molecular chain were important. These double bonds are the weakest part of the chain as they are most active chemically. A chain that contains many double bonds readily reacts with the oxygen and ozone leading to the degradation of rubber. Oxygen deterioration is the more common of the two types of attack and will be described briefly, remembering the ozone attack is similar except the rubber must be stretched for ozone to attack. Depending on the compound, oxygen attack will work in two ways. In natural rubber, the oxygen attack will decrease the tensile, elongation, flexibility and hardness. If the attack is severe, the end result may be rubber soup. In SBR the tensile, elongation, flexibility are decreased as hardness increases giving a brittle product. In NBR the tensile and hardness increase while elongation and flex decreases. This also gives a brittle product. The promoters of oxygen are heat (almost always associated with oxygen attack) and light. Heat increases the oxygen attack by creating more double bonds in the rubber. Oxygen attacks the double bonds and creates free radicals. The free radicals, in turn, react with the rubber molecules to give more double bonds and the process repeats. Oxygen attack accelerates once it starts. Anti-oxidants react with the free radicals to form a harmless by-product, thus stopping the cycle. In some cases they offer the oxygen a more active material than the double bond of the rubber molecule. This ties up the oxygen and prevents further attack. The main difference between oxygen (O_2) and ozone (O_3) attack is that ozone attack will only affect

rubber under tension. The ozone attack is always characterized by severe cracking. Anti-ozants prevent ozone attack by migrating to the surface and reacting with the ozone to form a harmless by-product. In some cases, waxes are used which form a barrier to the rubber. If the wax becomes cracked, the ozone attacks rapidly.

f. Reinforcing Agents - Reinforcing agents are used in the rubber compound to give strength to the compound and in many cases desired compression set characteristics. They are also extremely important for abrasion resistance. The primary reinforcing agent is Carbon Black. The story and chemistry of carbon black is as fascinating and complex as is rubber itself. There are many types of carbon black and methods of manufacture much too long and involved to go into here. The more common carbon blacks are Furnace Blacks, Channel Black, and Thermal Blacks, each type black having individual characteristics to impart to the rubber. The particle size, the pH and the structure (single particles or chain) are the most important properties of carbon black. The carbon black gives strength to the rubber, regulates compression set, increases hardness, reduces elongation, increases abrasion resistance and tear strength.

g. Fillers - Fillers are used in rubber to (1) sometimes as a coloring agent, (2) primarily to reduce cost. Fillers have some effect on certain properties of the finished compound; i.e. hardness, but in general do not have a pronounced effect.

Fillers used with rubber are clay, silicas, whitings, mica, cork, asbestos, zinc oxide, and many more too numerous to mention.

All the ingredients necessary to make rubber rings are now present. The raw stock (natural rubber, SBR or NBR, plasticizers, sulfur, reinforcing agent filler, accelerators, anti-ozonants and anti-oxidants.

These materials are all combined (in their proper amounts in a mixer - Banbury), thoroughly mixed (very important), sheeted, extruded into a round cross section, color coded, placed into a compression mold and vulcanized.

B. Vulcanization

The vulcanization is the most important step in the manufacture of any rubber article, for no matter how well the formula (recipe) has been made and mixed, how good the raw rubber is, it is all for nought if the vulcanization is not right.

Vulcanization is named after the Roman God Vulcan, the god of fire, who was also supposed to be familiar with sulfur. Today definition of vulcanization is any treatment that decreases the plasticity of the rubber at the same time maintaining its elasticity.

What is believed to happen in vulcanization is that cross links occur at points in the rubber molecule (at some of the double bonds). In the previous analogy of the rubber polymer being like a linked chain, each chain was separate to itself. After vulcanization these chains are cross linked to each other at regular intervals. Another analogy is the unsured rubber is like two lengths of rope. After vulcanization the ropes are joined so that a rope ladder results. This prevents movement in all directions but does not limit stretch in the original direction more than previously. The more sulfur present the more cross linking and the harder the rubber. Vulcanization is accomplished by time and temperature.

The proper, or optimum, cure for a given compound is determined in the laboratory. This is usually accomplished by curing the compound at different lengths of time and at different temperatures. Specimens are taken from these different cured compounds and tests run on them. From these tests the optimum cure is determined. The most common test used for this purpose is the best tensile strength plotted against the modulus at 300% elongation (Modulus is pounds required to stretch the compound to the desired elongation). In many cases, however, the laboratory will use the test that is most critical for the end use function of the product to determine optimum cure; in the case of "Fluid-Tite" rings, the compression set test. In other words the proper temperature and length of time at that temperature to give the lowest compression set is determined. It is in vulcanization that accelerators are necessary. They act as a catalyst to the sulfur linkage and greatly reduce the time cycle. The average temperature for vulcanization is 280 F. for 20 minutes in the case of rubber rings. Of course these times will vary between NR, SBR and NBR, with NBR being the longest (25 minutes) and SBR the shortest (15 minutes). In some cases the time will be reduced by increasing the temperature.

The two main dangers of vulcanization are overcure and undercure. Overcure may be shown in two ways for SBR and NBR. The hardness increases, the modulus increases, the tensile and elongation drop off. In NR the rubber reverts to its original properties, lower hardness, modulus and tensile and higher elongation. For this reason it is desirable to obtain cures that have a long plateau; that is, when the compound reaches its maximum cure it will maintain these properties even though the temperature may be held for additional lengths of time. When the compound is undercured, it leaves the finished product with properties somewhere between the raw state and the desired level. The aging characteristics are particularly poor in undercured compounds.

8.0 Specifications

After the "Fluid-Tite" rings are cured and trimmed (getting rid of excess flashing), there must be assurances that they will perform satisfactorily the purpose intended. These assurances are obtained by means of specifications. Specifications are designed so that the properties believed to be necessary for a ring to satisfactorily perform the service intended are put forth and the methods of testing to make sure these requirements are met.

There are two main specifications governing "Fluid-Tite" rings:

(1) ASTM Specification D 1869-63T -- "Rubber Rings for Asbestos Cement Pipe"

(2) CPC Purchase Specification No. 503 -- "Fluid-Tite" Rings.

Since all the requirements of ASTM C 1869-63T are included in CPC No. 503, only the latter will be discussed.

The more important tests and the reasons for having them are given. It should be pointed out that wherever possible ASTM Test Methods are used as this gives the producer and consumer common grounds on which to compare results. Also these test methods are time tested and under the vigilance of some of the best rubber men in the country. The tests are:

A. Tests

(1) Tensile Strength - The tensile strength is determined on specimens taken from the finished rings. This test is conducted on the specimens "as received" and after oven aging. The tensile strength on the "as received" specimens is to determine if the rings were

made from a high quality raw rubber. The test on the aged specimens is an indication of how the rings will hold up in usage. (It should be emphasized that the service conditions of coolness, darkness, and moistness are ideal conditions for rubber rings). The test after aging is also an indication that the rings were properly cured.

(2) Elongation - This test determines the elasticity of the rubber compound. How far it will stretch before breaking. This test is conducted at the same time on the same specimens as the tensile strength test, on both the "as received" and aged state. When the results of this test are used in conjunction with the results of the tensile strength test, it is an excellent indication of cure. For instance, a low tensile and high elongation of a natural rubber compound would indicate either over or undercure (improper cure). On the other hand a high tensile and low elongation on an NBR compound would indicate an overcure. A low tensile and low elongation on an SBR compound would indicate overcure while a low tensile and high elongation would indicate undercure. These tests are also valuable in indicating the uniformity of the rings from shipment to shipment.

(3) Modulus at 300% Elongation - This gives an indication of the "nerve" of the stock. In practical application a high modulus (lbs. to stretch the rubber 300% of its original length) would indicate very hard assembly effort. A low modulus would indicate a weak compound and danger of blow-out.

(4) Hardness - Performed on the rings and specimens in the "as received" and after aging condition. When performed on the rings "as received", it is a control test that determines the uniformity of the rings from shipment to shipment and also that the rings are within hardness limits of what is known to perform satisfactorily in service. When performed on rings and specimens after aging (exposure to both heat and water), it is an indication of how the ring will "stand up" upon exposure and in service. Excessive changes in hardness on aged rings or specimens would cause investigation of the compound. The excessive change in hardness would not necessarily point out the cause, but show that something is wrong.

The hardness test is by use of a durometer and is the measure of the resistance to the indentor point penetration by the rubber.

(5) Compression Set - This is the most important test run on the "Fluid-Tite" ring. This test determines that when the ring is confined in the pipe and coupling, it will continue to exert pressure against both the pipe and coupling groove. Compression set measures the amount of permanent set the ring will take. Knowing the dimensions of the pipe, coupling, and ring and the amount of permanent set, it can easily be determined whether the ring will continue to exert pressure or not.

(6) Water Immersion - This test is conducted at elevated temperatures and is an aging test. This test determines if the compound will break down in water. There are dangers in this test as some material could be taken from the compound and replaced with water. The change would be hard to detect.

(7) Shrinkage--not ASTM - This test is also a water immersion test with a drying process added. The whole ring is used and the change in dimensions recorded. This is a very severe but very necessary test to avoid the possibility of ring shrinkage in service.

(8) Ozone Resistance - This test determines the resistance of the rubber to ozone attack. In effect it is to determine if sufficient anti-ozinant is present in the compound.

(9) Low Temperature Flexibility - This is to determine that the rings may be used in cold weather without breaking or cracking.

(10) Oil Immersion - MER Only. This test is to determine whether aliphatic oils or solvents (primarily petroleum) will cause the MER compound to swell or lose its physical properties to the point where it would be useless.

(11) Assembly Effort--not ASTM - This test is conducted on finished rings at room temperature and at 10°F. The test determined the amount of force necessary to assemble a pipe and coupling. The test is performed

using standard pipe and coupling and measuring the force necessary to assemble them. A very high assembly effort would indicate an unsuitable compound as it might lead to forcing the ring out of the coupling groove rather than compress it. The low temperature (10°F) is important for the same fact.

The standard aging temperatures and time for NR and SBR compounds for the tensile strength and elongation tests are 158°F for 168 hrs. The compression set test is conducted on specimens from finished rings compressed 50% and exposed to 158°F temperature for 22 hrs.

The standard aging temperature and time for NBR compounds for the tensile strength and elongation tests are 212°F for 70 hours. The compression set test is conducted on specimens from finished rings compressed 50% and exposed to 212°F for 22 hrs.

The water immersion test on all compounds is conducted at 210°F for 21 days. The shrinkage test on all compounds is submerged in tap water at room temperature for 168 hrs. followed by drying in an oven at 158°F for 168 hours.

The test requirements of "Fluid-Tite" rings are severe in order to maintain high quality rings, however it is known that no specification is perfect and that a great deal of the success of "Fluid-Tite" rings depend on the integrity of the supplier and the knowledge of the compounder. CPC is fortunate in having suppliers that have both these much needed attributes.

Presently CPC uses two types of compounds for "Fluid-Tite" rings: NR, natural rubber, and NBR - Buna N or oil resistant.

The natural rubber is used in most rings as the NBR is not in as much demand. Natural rubber is used because it has the best properties necessary for successful usage of "Fluid-Tite" rings. The drawbacks of natural rubber are low temperature range (it should not be used in pipelines subjected to over 120°F. over an extended time), and the anti-ozonant and anti-oxidant properties must be added to the compound.

The NBR (Buna N) compound is more expensive and is, therefore, only used in lines where oils might be present. This compound has excellent properties, its main drawback being that it is very difficult to add anti-ozonants to it because of a compatibility problem.

SBR has not been used mainly because the naturel rubber has been plentiful and has done an excellent job.

As can be seen, the enemies of rubber are light and heat. The rings are packed in cartons and stored in a cool place. In service the conditions are ideal -- cool and moist, both conducive to long life for the rubber compound.

In the future, as more and more new polymers are being developed, it is hoped that a single ring can be developed that will be oil resistant, have reasonable cost, will be able to withstand 300°F. temperature, have natural anti-oxidant and anti-ozonant properties and have compression set properties even better than the present.

EPILOGUE

Rubber gaskets installed over 100 years ago are still performing satisfactorily in Europe and England. With the many improvements in manufacturing methods, refinements to machinery, and the rapidly advancing new polymers since that time, there is every reason to believe and expect an even longer life from the present day "Fluid-Tite" gaskets.

It is hoped this paper leads to a better understanding of the use, properties and problems associated with rubber rings and a promise of even better rings in the days to come.