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LITERATURE SURVEY ON THE EFFECTS OF LONG-TERM SHELF AGING ON ELASTOMERIC MATERIALS

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TECHNICAL REPORT AFML-TR-67-235

MARCH 1968

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FOREWORD

This report was prepared by Monsanto Research Corporation, Dayton Laboratory, under Air Force Contract No. AF 33(615)-1484, and was initiated under Project 7381, "Materials Applications," Task 738102, "Materials and Processes Evaluation."

The work was administered under the direction of the Materials Applications Division, Air Force Materials Laboratory, Directorate of Laboratories, Wright-Patterson Air Force Base, Ohio, with Mr. Phillip A. House as project engineer.

This report covers work performed from November 1965 to November 1966, at the Dayton Laboratory of Monsanto Research Corporation, and was submitted August 1967 for publication.

The survey was performed by Carmen L. Bellanca with Jay C. Harris serving as project Manager.

This technical report has been reviewed and is approved.

Albert Olevitch
Albert Olevitch, Chief
Materials Engineering Branch
Materials Application Division
Air Force Materials Laboratory
ABSTRACT

Literature was surveyed with regard to the effects of long-term storage on the properties of elastomeric compounds. Data showed that most elastomeric compounds aged well. Elongation at break appeared to be the property most commonly affected by age deterioration, although compression set and change in strain also are affected.

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II SUMMARY AND CONCLUSIONS</td>
<td>2</td>
</tr>
<tr>
<td>III RECOMMENDATIONS</td>
<td>3</td>
</tr>
<tr>
<td>IV DISCUSSION</td>
<td>4</td>
</tr>
<tr>
<td>A. Rubber Manufacturers' Association</td>
<td>6</td>
</tr>
<tr>
<td>B. O-Ring Manufacturer's Data</td>
<td>11</td>
</tr>
<tr>
<td>C. Mare Island Naval Shipyard Rubber Laboratory</td>
<td>11</td>
</tr>
<tr>
<td>D. Pensacola Naval Air Station - Materials Engineering Division</td>
<td>11</td>
</tr>
<tr>
<td>E. Precision Rubber Products</td>
<td>11</td>
</tr>
<tr>
<td>F. Rock Island Arsenal</td>
<td>12</td>
</tr>
<tr>
<td>G. Oklahoma City Air Material Area (OCAMA)</td>
<td>12</td>
</tr>
<tr>
<td>H. Mobile Air Material Area</td>
<td>13</td>
</tr>
<tr>
<td>I. Compression Set Aging Study - OCAMA</td>
<td>14</td>
</tr>
<tr>
<td>J. Society of Automotive Engineers (SAE)</td>
<td>14</td>
</tr>
</tbody>
</table>

APPENDIX

Figures 1 - 5
Tables I - XXIX

REFERENCES
<table>
<thead>
<tr>
<th>Figure</th>
<th>Illustration Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Neoprene: Effect of Aging on Elongation at Break ($E_B$).</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Nitrile: Effect of Aging on Elongation at Break ($E_B$).</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>Effect of Aging at Various Temperatures on Ultimate Elongation.</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>Percent Change in Strain with Time After Aging Indoors.</td>
<td>19</td>
</tr>
<tr>
<td>5</td>
<td>Percent Change in Strain with Time After Aging Outdoors.</td>
<td>20</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Physical Properties of Vulcanizates Aged Indoors Ten Years (Percent Change from Original Values)</td>
<td>21</td>
</tr>
<tr>
<td>II</td>
<td>Physical Properties of Vulcanizates Aged Outdoors Ten Years (Percent Change from Original Values)</td>
<td>22</td>
</tr>
<tr>
<td>III</td>
<td>Strain Data for Heat Aged Vulcanizates</td>
<td>23</td>
</tr>
<tr>
<td>IV</td>
<td>Strain Data for Indoor Aged Vulcanizates</td>
<td>24</td>
</tr>
<tr>
<td>V</td>
<td>Strain Data for Outdoor Aged Vulcanizates</td>
<td>24</td>
</tr>
<tr>
<td>VI</td>
<td>Physical Property Change of Commercial Nitrile Compounds - RMA</td>
<td>25</td>
</tr>
<tr>
<td>VII</td>
<td>Physical Property Change of Commercial Neoprene Compounds - RMA</td>
<td>25</td>
</tr>
<tr>
<td>VIII</td>
<td>Physical Property Change of Butyl Rubber Compounds - RMA</td>
<td>26</td>
</tr>
<tr>
<td>IX</td>
<td>Physical Property Change - MIL-P-5516, Class B - RMA</td>
<td>26</td>
</tr>
<tr>
<td>X</td>
<td>Physical Property Change - MIL-G-5510A and MIL-P-5315A Compounds - RMA</td>
<td>27</td>
</tr>
<tr>
<td>XI</td>
<td>Physical Property Change - MIL-P-25732 and MIL-P-18017 Compounds - RMA</td>
<td>27</td>
</tr>
<tr>
<td>XII</td>
<td>Physical Property Change of Overage O-Rings - Manufacturer's Data</td>
<td>28</td>
</tr>
<tr>
<td>XIII</td>
<td>Physical Property Change of Overage O-Rings - Manufacturer's Data</td>
<td>29</td>
</tr>
<tr>
<td>XIV</td>
<td>Effect of Shelf Aging on MIL-P-5516 O-Rings - Mare Island Naval Shipyard</td>
<td>30</td>
</tr>
<tr>
<td>XV</td>
<td>Physical Properties of Aged Vulcanizates - Precision Rubber</td>
<td>31</td>
</tr>
<tr>
<td>Table</td>
<td>The Effect of Shelf Storage Life on the Physical Properties of Silicone, Fluorosilicone, and Fluorocarbon Vulcanizates</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>XVI</td>
<td>O-Ring Physical Properties After Storage - OCAMA - MIL-P-5516 - Manufacturer A</td>
<td>32</td>
</tr>
<tr>
<td>XVII</td>
<td>O-Ring Physical Properties After Storage - OCAMA - MIL-P-5516 - Manufacturer B</td>
<td>33</td>
</tr>
<tr>
<td>XVIII</td>
<td>O-Ring Physical Properties After Storage - OCAMA - MIL-P-5516 - Manufacturer C</td>
<td>34</td>
</tr>
<tr>
<td>XIX</td>
<td>O-Ring Physical Properties After Storage - OCAMA - MIL-P-5515 - Manufacturer D</td>
<td>35</td>
</tr>
<tr>
<td>XX</td>
<td>O-Ring Physical Properties After Storage - OCAMA - MIL-P-5515 - Manufacturer A</td>
<td>36</td>
</tr>
<tr>
<td>XXI</td>
<td>O-Ring Physical Properties After Storage - OCAMA - MIL-P-5315 - Manufacturer A</td>
<td>37</td>
</tr>
<tr>
<td>XXII</td>
<td>O-Ring Physical Properties After Storage - OCAMA - MIL-P-5315 - Manufacturer B</td>
<td>38</td>
</tr>
<tr>
<td>XXIII</td>
<td>O-Ring Physical Properties After Storage - Mobile - MIL-P-5516 - Manufacturer A</td>
<td>39</td>
</tr>
<tr>
<td>XXIV</td>
<td>O-Ring Physical Properties After Storage - Mobile - MIL-P-5516 - Manufacturer B</td>
<td>40</td>
</tr>
<tr>
<td>XXV</td>
<td>O-Ring Physical Properties After Storage - Mobile - AMS-7270</td>
<td>41</td>
</tr>
<tr>
<td>XXVI</td>
<td>O-Ring Physical Properties After Storage - Mobile - AMS-7271</td>
<td>42</td>
</tr>
<tr>
<td>XXVII</td>
<td>O-Ring Physical Properties After Storage - Mobile - AMS-7274</td>
<td>43</td>
</tr>
<tr>
<td>XXVIII</td>
<td>O-Ring Physical Properties After Storage - Mobile - MIL-P-5315 - Manufacturer A</td>
<td>44</td>
</tr>
<tr>
<td>XXIX</td>
<td>Stored O-Ring Physical Property Change After Oven Aging - Monsanto - MIL-R-7362 O-Rings</td>
<td>45</td>
</tr>
</tbody>
</table>
SECTION I

INTRODUCTION

There presently exist military standards which are intended as guides for use by storage activities involved in the supply of rubber products. Generally, these standards have established maximum time periods for the shelf storage life of rubber products. The shelf storage life refers to the maximum period of time from cure date, during which the item is expected to retain its ability to function as originally specified. Since maximum storage periods are recommended, rubber goods are either disposed of at the end of the storage periods or updated by the testing of certain physical properties and determining whether the rubber is still useful.

As long-term storage data which define the effect of shelf storage of long periods on elastomeric physical properties are generated, it is becoming more apparent that the life expectancy of specification rubber items when stored under normal military conditions is somewhat longer than heretofore believed. The data point out that reconsideration of age control over these items may be in order.

Consequently, this literature survey was conducted with regard to the effect of long storage times (i.e., 10 years) on the physical properties of molded rubber products corresponding to various military specifications. Additional literature which was felt to be of value in elucidating the aging properties of elastomers was surveyed. This survey describing elastomeric aging is by no means a complete one since the literature in this area is voluminous; consequently, the only literature studied was that considered most directly pertinent.
Literature was surveyed with regard to the effects of long-term storage on the properties of elastomeric compounds. The survey was undertaken to determine whether present age control restrictions on military specification elastomeric materials should be reconsidered.

Long-term storage data pointed out that, in general, elastomeric compounds which met military specifications aged well under normal military storage conditions. Most compounds showed fairly good retention of the original physical properties after storage periods as long as ten years.

The property showing the greatest change after prolonged storage periods was tensile modulus. This was not surprising, since the elongation of most elastomers tested tended to decrease while the ultimate tensile strength either increased from the original or showed little change.

Great changes in modulus levels did not appear to define realistically the extent of degradation. Elongation at break appeared to be the parameter most commonly affected by aging. Other parameters affected were compression set and change in strain at constant load with time.
SECTION III
RECOMMENDATIONS

Based on long-term storage data from tests conducted by Air Force Air Material areas and by the Rubber Manufacturers’ Association, it is recommended:

(1) that the matter of age control restrictions on stored rubber items be reconsidered. The data show that storage limitations on many specification materials can be loosened to increase maximum storage times.

(2) that the properties after high temperature aging of stored elastomers be further evaluated. Data by Mobile AMA indicate that stored MIL-R-7362 Buna N would meet original physical property requirements, but requirements after aging at 275°F could not be met. Tests by Monsanto Research Corporation supported the Mobile data.

(3) that consideration be given to new standards of judging the suitability of stored specification materials rather than just the determination of physical property changes upon shelf aging. Commonly reported shelf aging data indicate changes in stress-strain, hardness, and modulus. However, it is becoming increasingly evident that these parameters do not fully characterize age deterioration. Testing of properties such as compression set, strain, and stress relaxation would appear to indicate more readily small changes in materials due to aging.

(4) that long-term aging tests be conducted on silicone and fluorocarbon elastomer compounds. Very little long-term storage data are available for these high performance materials, and increasing usage of them warrants background information on their long-term stability.
SECTION IV
DISCUSSION

Shelf aging of elastomers is a slow process which generally takes place over a number of years. However, it often is desirable to be able to predict the life and/or the degree of deterioration of elastomeric articles after a storage period. Since it is difficult, if not impractical, to obtain the necessary physical property degradation data from long-term aging studies (e.g., 10 years) prior to use, accelerated aging tests have been designed. These such as oven aging, oxygen and ozone exposure, and fluid immersion are well-known throughout the rubber industry.

An overall change in physical properties generally results from accelerated aging tests. Changes can be misleading at times because the relationship between the degree of change and the extent of degradation is inconclusive. Tensile, modulus, and hardness can either increase or decrease upon oven aging of elastomers, whereas elongation only decreases.

Ultimate elongation appeared to be the most representative property to express the deterioration of elastomeric compounds with age. Mandel, et al. (1), made a mathematical study of aging data reported in the literature. The following equation was developed from this work and expresses the elongation at break after room temperature aging:

\[ E = E_0 - kt^{0.5} \]  \hspace{1cm} (1)

where \( E \) is the elongation at break after aging for time \( t \), \( E_0 \) is the extrapolated elongation at time zero, and \( k \) is a velocity constant.

Utilizing this equation, Stokoe (2) attempted to estimate the service life of nitrile and neoprene compounds under various conditions. Experimental data obtained for elongation at break were plotted according to the above equation; the plots are given in Figures 1 and 2. As shown, the points approximate a straight line. If we assume 100 percent elongation at break to be the criterion of failure, then the life of the neoprene compounds is approximately 16 years outdoors and 30 years indoors. The nitrile compounds would be serviceable for 25 years indoors and 12 years outdoors. This predicted life assumes no unusual factors.
Cosgarea, et al. (3), aged nitrile O-rings at 25°, 50°, 65°, 80°, and 100°C from 2 to 240 days. The ultimate elongation data were correlated as a function of time according to Mandel's equation in an attempt to predict aging properties. Results obtained at 100°C were discarded due to the possibility of a different aging reaction mechanism at this high temperature. From the data reduction, the predicted time for a 20% reduction in elongation ranged from 2.25 to 2.75 years at 25°C; the predicted time to reach an ultimate elongation of 150% ranged from 6.50 to 7.33 years.

The equation developed by Mandel, et al., expresses the early part of the aging process, e.g., room temperature aging up to 10 years. However, the prediction of shelf aging from tests at two or more elevated temperatures is possible only if the relationship between aging and temperature is known.

Mandel, et al. (1), treated the parameter k as a reaction rate constant, assuming the decrease in ultimate elongation upon aging to be the result of a single chemical reaction. If this is true, then according to the Arrhenius equation,

\[ \ln k = \frac{-\Delta H}{RT} + C \]  

a plot of ln k versus 1/T should be linear. This was indeed the case as shown in Figure 3. As noted, the curves appear to be linear. However, as the test temperature increased, the rate of aging increased much faster than predicted.

Bergstrom (4) aged vulcanizates of styrene-butadiene (SBR), neoprene, butadiene-acrylonitrile (NBR), and butyl indoors and outdoors for 10 years under unstressed conditions. Air oven aging tests were conducted at 158°F concurrently to determine if any correlation existed between accelerated and natural (indoor and outdoor) aging.

Figures 4 and 5 show the change in strain over the 10-year aging period. Tables I and II summarize the changes in tensile, elongation, hardness, and strain at 200 psi load. It is seen that the butyl vulcanizate aged less over the 10-year period than any of the other vulcanizates. This was probably due to the lower degree of unsaturation in the butyl chain compared to the other test polymers. Aging degradation is generally associated with unsaturation; i.e., the less the unsaturation, the less the degradation. Further, it was shown that the vulcanizates aged more outdoors than indoors. However, from these data, all of the compounds tested could be considered useful after 5 years of aging, depending upon the application.
Specimens of representative vulcanizates were aged at 158°F from 1 to 419 days. Percent retention of strain data are given in Table III; these data are compared to indoor and outdoor data shown in Tables IV and V. It is noted that aging vulcanizates for periods up to as much as 20 days at 158°F did not have the expected deleterious effect on strain properties. It appeared that oven aging at 158°F was not a severe enough accelerated test for indoor-aged SBR, neoprene, and NBR vulcanizates as indicated by the data of Tables IV and V.

In other work, Bergstrom (5) attempted to correlate natural aging with accelerated aging at 212°F of SBR, natural rubber, and NBR compounds. The vulcanizates were aged indoors and outdoors up to six years. Air oven aging tests were conducted at 212°F for periods from 70 hours to 14 days. It was found that the relative resistance to deterioration of different types of elastomers could be predicted reasonably well from the accelerated aging tests. However, no direct correlation existed between oven and natural aging for a particular elastomer. The resistance to age degradation of a particular elastomer varies according to the ingredients it contains, i.e., antioxidants, antiozonants, acceleration system, plasticizer type, etc. As a consequence, it became apparent that to attempt to predict the effect of natural aging solely on accelerated aging data would be futile.

A number of programs were undertaken to determine (1) the effect of long-term shelf aging on elastomer physical properties, and (2) serviceability after long periods of storage and field service. Summaries of these programs follow. In selecting representative data for the condensed tables, it was difficult if not impossible to follow one single compound or composition throughout. Either the data were insufficiently identified, or data points, selected by those reporting the data, which skipped periods not leading to a clear-cut follow through. The objective in any event was to select representative values and to cite extremes rather than presenting every data value given in original reports.

A. RUBBER MANUFACTURERS' ASSOCIATION

The Rubber Manufacturers' Association (R.M.A.), O-Ring Division, studied the degradation of tensile, elongation, modulus, and hardness properties of O-rings of a variety of compounds submitted by several member companies (6). The intent of the program was to test for periods of 10 to 20 years.

The materials tested include commercial nitrile, commercial neoprene, butyl rubber, and compounds which meet specification MIL-P-5516. Some of the participating members have submitted
additional types of materials. These include compounds conforming to military specifications MIL-G-5510, MIL-P-5315, MIL-P-18017, and MIL-P-25732. All of the specification materials are nitrile rubbers. Representative data are shown in Tables VI-XI.

1. Effect of Aging on Commercial Nitrile Compounds (Table VI)

a. Modulus at 100% Elongation

Aging of several commercial nitrile compounds showed that the modulus at 100% elongation changed the most of the physical properties evaluated. It might be suspected that extremes of modulus could occur at periods of exposure less than the maximum. That this was the case was true for one compound which after 2 years exposure showed a 53% increase. Other compounds after 6 years exposure varied from +15% to 49% with values as low as 8% after 5 years. The data of Table VI represents the values for three more typical compounds selected from a total of 17, up to a maximum of 7 years exposure.

b. Elongation

According to data reported for 17 compounds, the elongation at break generally decreased with time. After 6 years of aging, the maximum elongation change was -27%. In some cases, the change in elongation was as low as -4% after 6 years. In general, after the initial change in elongation (1 to 1.5 years), any subsequent change was usually of the same magnitude. There did not appear to be gross changes in elongation over the 7-year period.

c. Tensile Strength

After 7 years aging of 17 compounds, the maximum change in tensile strength was +21%. In one case, change in ultimate tensile strength after 7 years was +1.0%. Tensile strength of the tested compounds was generally level through 4 years of aging. Further, the greatest change usually occurred in the first year or two and then leveled off.

d. Hardness

Hardness data were obtained from 11 compounds and showed an average change of +5 points after 7 years. The maximum change noted was +10 points. The hardness of the compounds tended to increase slowly with time, although this was not unexpected.
Generally, the nitrile compounds under test showed no gross degradation after 7 years of storage. However, the extent of degradation is relative because it is dependent upon the limits set in material specifications and the specific application. For example, a particular item covered by a specification allowing only a five-point increase in hardness might show a ten-point increase after 7 years of storage, and could possibly still be considered usable.

2. Effect of Aging on Commercial Neoprene Compounds (Table VII)

a. Modulus at 100% Elongation

As in the case of the nitrile compounds, modulus at 100% elongation of the neoprene compounds evaluated showed the greatest change. Five compounds were tested. One showed an increase in modulus of 125% after 7.75 years. Other of the five compounds not included in the table ranged from 33% to 111%. Large increases (24% to 56%) were noted after only 1.25 years of storage. A steady increase was noted thereafter.

b. Elongation

The ultimate elongation loss for all of the five compounds averaged approximately 35% after 7.75 years of storage. The elongation decrease during the first year of storage and thereafter remained essentially constant.

c. Tensile Strength

Generally, the ultimate tensile strength of the compounds evaluated did not show much change through 7.75 years of storage. Change in tensile strength in most cases appeared to reach a maximum at approximately 2 years and to level off thereafter. One compound showed a tensile strength decrease of 22.7% after 7.75 years; at 2 years it had decreased 14%.

d. Hardness

All of the neoprene compounds increased in hardness to approximately the same degree (8-10 points) after storage for 7.75 years. The increase in hardness appeared to remain constant for the last 4 to 5 years after increasing rather rapidly early in the storage period.
3. Effect of Aging on Commercial Butyl Compounds (Table VIII)

a. Modulus at 100% Elongation

Limited data from four compounds are available from the R.M.A. study which characterized the change in modulus of butyl with time. The limited study showed that one compound had an increase of 87% in modulus after 5.75 years of storage, another +9.2% after 4 years, and another +12% after only 1.75 years of storage. These data pointed out the wide variation in age resistance possible within specific elastomer classes through compounding techniques.

b. Elongation

The changes in ultimate elongation varied widely, e.g., -6% to -28% at 5.75 years, -20% at 1.75 years. This again pointed out the variation in properties obtainable from a single elastomer through compounding techniques.

c. Tensile Strength

The ultimate tensile strength of butyl compounds stored 7.75 years increased approximately 12% to 16%. None of the compounds tested show excessive changes through the test period.

d. Hardness

The change in hardness of the butyl compounds showed no set pattern and was probably dependent on compounding techniques. For example, after 7.75 years of storage, one compound increased 10 points in hardness, while another lost 1 point. Only limited data were available on other compounds, but they indicated slight change, i.e., +1 after 4 years, +1 after 1.75 years.

4. MIL-P-5516, Class B Compounds (Table IX)

a. Modulus at 100% Elongation

Modulus data were reported from four compounds meeting the above specification. The data showed that wide variations in modulus were obtained even though all compounds were directed toward the same specification. One compound showed over 85% increase in modulus after 6.75 years of storage, while a second, not shown, increased 24% in 7.25 years.
b. Elongation

The compounds showed fairly good retention of ultimate elongation through 4.75 years of storage (-14.4% max.) and increased to a maximum of -23.7% after 5.75 years. All O-rings still had at least 150% elongation, which should be sufficient for most applications.

c. Tensile Strength

None of the O-rings tested showed great changes in tensile strength after 6.75 years of storage. The maximum change noted was +22% (not shown) after 4.25 years; the minimum was -0.20% after 7.25 years, also not shown.

d. Hardness

No great changes in hardness were noted after 7.75 years of storage at room temperature. The maximum change was +14 points (not shown) after 7.5 years. A change to this extent may be considered excessive for specific O-ring applications (i.e., loaded O-rings).

5. MIL-G-5510A and MIL-P-5315A Compounds (Table X)

Since only three compounds were tested, limited data were available on these compounds. None of the tests showed great changes in tensile strength or hardness after 7.5 years of storage. One compound showed an appreciable decrease in ultimate elongation (-41%); whether the O-rings are serviceable would depend on the specific application. Very limited data showed an increase in modulus through 7.5 years storage of 34% and another, not shown, of +68.1% after 7.75 years.

6. MIL-P-25732 and MIL-P-18017 Compounds (Table XI)

Very limited long-term storage data were available on these compounds; two compounds representative of MIL-P-25732 and one for MIL-P-18017 were tested. Only one had been stored as long as 7.5 years. Data showed an appreciable increase in hardness (+15 points) after 7.5 years, but relatively small changes in ultimate tensile and elongation (+19% and -23%, respectively). The small changes in properties imply that the O-rings are still serviceable.
B. O-RING MANUFACTURER'S DATA

In 1963, some Buna N O-ring manufacturers conducted tests of average samples of their O-rings returned by Mobile Air Materiel Area. These represented Specifications MIL-P-5516, MIL-P-5315, AMS-7274, and AMS-7270. The O-rings were 5 to 7.5 years old.

The test results indicated that all the O-rings evaluated were considered still serviceable. Representative data are shown in Tables XII and XIII. The most appreciable change was found in ultimate elongation, but the particular O-rings maintained sufficient elongation for usage. No large changes in hardness or tensile strength were observed, and many showed small decreases in ultimate elongation.

C. MARE ISLAND NAVAL SHIPYARD RUBBER LABORATORY

The Rubber Laboratory of Mare Island Naval Shipyard investigated the effect of long-term shelf aging on O-rings conforming to Specification MIL-P-5516 (7). Data are shown in Table XIV. O-Rings which had reached the maximum allowable storage age of 4 years were tested after an additional 4 years of shelf aging. No significant changes in physical properties were observed after 8 years. It was concluded from these tests that the O-rings will give satisfactory service after at least 8 years of shelf aging.

D. PENSACOLA NAVAL AIR STATION - MATERIALS ENGINEERING DIVISION

The Materials Engineering Division of Pensacola Naval Air Station evaluated O-rings conforming to MIL-P-5315 (8) to determine the change in physical properties after extended storage and to determine whether age resistance was affected by extended storage. O-Rings aged 1 to 7 years were tested. Original physical properties, and properties after aging 70 hours and 168 hours at 212°F were recorded. No serious degradation in original properties or reduction in age resistance were found to result when O-rings were stored up to 5 years.

E. PRECISION RUBBER PRODUCTS

Precision Rubber Products Corporation, Dayton, Ohio, reported an in-house program (9) in which compounds of several elastomers have undergone shelf aging tests. Data obtained from neoprene and nitrile compounds were included in the R.M.A. program and will not be discussed here. However, compounds of SBR,
polyurethane, silicone, polyacrylate, and Viton were tested. These data are shown in Table XV. When the report was issued (1962) the Viton samples had only been aged one year; consequently, no conclusions can be made. The others were stored 6 years and showed very good retention of properties. All would be considered serviceable after 6 years storage.

F. ROCK ISLAND ARSENAL

Rock Island Arsenal conducted a limited 3-year program to determine the effect of shelf storage on the properties of silicone, fluorosilicone, and fluorocarbon vulcanizates (10). The data showed that tensile strength, modulus, elongation, hardness, and resistance to volume change did not change significantly over the 3-year storage period (Table XVI). However, the report pointed out that small changes in properties due to mild aging may not be detectable from the above tests. Changes in strain (elongation measured under constant load) and compression set were considered to be more sensitive measures. The silicone and high strength silicone compounds showed a significant decrease in set after 3 years of storage; this was attributed to increased crosslinking with time. Further, the high strength silicone showed an appreciable decrease in strain which would be expected from additional crosslinking.

The fluorocarbon compound showed very little change in compression set from the original 38%. Maximum set of 50% was reached at 2 years of storage; however, specimens aged 3 years decreased to a set of 41%.

G. OKLAHOMA CITY AIR MATERIAL AREA (OCAMA)

Oklahoma City Air Material Area, Tinker Air Force Base, evaluated O-rings conforming to MIL-P-5516 and MIL-P-5315 that had been stored for periods as long as 13 years (11). Representative test results are shown in Tables XVII - XX. The data shown in these tables are not from the same batch of O-rings carried throughout the yearly periods of test. They represent individual values and are to be compared with original specification values since all batches tested were of specification quality. Contributory to variation in the values obtained are variation in aging conditions, variation between batches, and normal variation in test operation.

As expected, 100% modulus values of 5516 O-rings showed the greatest change, increasing as much as 61% after 10 years in one case. However, very little change in tensile strength was noted,
and elongation change averaged approximately -30% after up to 10 years. The OCAMA conclusion was that packaged O-rings conforming to MIL-P-5516 have a shelf life of at least 10 years under normal Air Force storage conditions.

Tables XXI and XXII show typical changes in physical properties of 5315 O-rings for two manufacturers after storage periods. In general, little change was noted, which again would indicate that under normal storage conditions the O-rings still would be usable after at least 10 years of storage.

H. MOBILE AIR MATERIAL AREA

Mobile Air Material Area, Brookley Air Force Base (12) tested materials conforming to MIL-P-5516 that had been stored for 7 years; these elastomers showed good retention of physical properties.

Typical data are in Tables XXIII and XXIV. This data coincides with that generated by OCAMA. Contributing to apparent variation in values obtained is the fact that differing batches of O-rings were involved, and the values cited do not follow a natural sequence from start to finish. Instead, since all the batches initially passed specification requirements, the comparison is made with these initial values, the changes over the storage periods then indicating trends and long term compliance with specification requirements. Specification materials covered by AMS-7270 (Table XXV), -7271 (Table XXVI), -7274 (Table XXVII), and MIL-P-5315 (Table XXVIII) were evaluated after 6 to 7 years storage. All were considered satisfactory as evidenced by the representative data shown in the tables. A recommendation was made that the shelf life of these specification materials be extended to 8 years.

As part of the same test program, 38 tests were run on average material covered under MIL-R-7362, and only 7 passed. It was found that in most cases, the material met the original requirement but could not stand up under the 275°F test requirement. As a follow-up to this phase of the test program, Monsanto Research Corporation tested 3 sets of stored O-rings after 275°F aging. One set was 3 years old, another 7 years old, and the last 11 years old. The test data are shown in Table XXIX. The only O-rings to pass the heat aging requirement was the 3-year-old set; the others showed excessive decrease in elongation and were considered to have failed. These results are still not conclusive since the O-rings that failed were all from the same manufacturer. This is an area that should be further investigated.
I. COMPRESSION SET AGING STUDY - OCAMA

A long term compression set study of MIL-P-5516 O-rings is currently in progress at OCAMA. The program was started July 1964.

The O-rings, supplied by three different companies, were put under 30 percent compression and immersed in MIL-H-6083 hydraulic oil at 750°F. Periodically the O-rings are removed, measured, then put back under compression and reimmersed. The compression set data, expressed as a percentage of the original deflection, are shown in Table XXX.

The data show that an increase in compression set occurs with time, as would be expected. Further, there appears to be little difference in set resistance with supplier.

J. SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

Currently in progress is a fluorocarbon elastomeric O-ring aging study conducted by SAE. Four laboratories are participating in this study. The O-rings are evaluated after aging in the unconfined state and under 25 percent compression. Data through three years are shown in Table XXXI.

The data show that a wide divergence of values for the physical properties exist between the laboratories. The only trend noted in the data was the increase in compression set with aging and that the increase in set appears greater with the compressed O-rings. All other properties tested seem to have undergone minimum change through the three-year period.
APPENDIX

Figures 1 - 5
Tables I - XXVIII
Figure 1. Neoprene: Effect of Aging on Elongation at Break ($E_B$).
Figure 2. Nitrile: Effect of Aging on Elongation at Break ($E_B$).
Figure 3. Effect of Aging at Various Temperatures on Ultimate Elongation.
Figure 4. Percent Change in Strain With Time After Aging Indoors.
Figure 5. Percent Change in Strain With Time After Aging Outdoors.
<table>
<thead>
<tr>
<th>Aging Time Periods</th>
<th>SBR (T E H S)</th>
<th>Neoprene (T E H S)</th>
<th>NBR (T E H S)</th>
<th>Butyl (T E H S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>1930 420 56 149</td>
<td>1780 330 53 68</td>
<td>1370 340 64 74</td>
<td>1910 720 45 199</td>
</tr>
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<td>-5 +6 +28 -25</td>
<td>+3 -2 +9 -22</td>
<td>+9 +15 +2 +9</td>
</tr>
<tr>
<td>2 years</td>
<td>+29 -12 +27 -66</td>
<td>-13 -6 +42 -47</td>
<td>+12 -6 +16 -17</td>
<td>+7 +18 +11 +24</td>
</tr>
<tr>
<td>3 years</td>
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<td>-18 -3 +25 -50</td>
<td>+7 0 +8 -26</td>
<td>-8 +13 -1 +21</td>
</tr>
<tr>
<td>4 years</td>
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<td>-23 -21 +38 -52</td>
<td>+27 -15 +9 -31</td>
<td>+10 +18 +2 +5</td>
</tr>
<tr>
<td>5 years</td>
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<td>-14 -18 +36 -50</td>
<td>+32 -18 +11 -39</td>
<td>+11 +8 0 +16</td>
</tr>
<tr>
<td>6 years</td>
<td>+4 -36 +18 -71</td>
<td>-17 -21 +36 -54</td>
<td>+28 -18 +11 -43</td>
<td>+10 +14 -4 +5</td>
</tr>
<tr>
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<td>+35 -18 +13 -49</td>
<td>+7 +10 0 +7</td>
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<tr>
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<td>+4 +11 +7 +1</td>
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<tr>
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<td>+16 -24 +14 -49</td>
<td>+1 +7 +7 +1</td>
</tr>
<tr>
<td>10 years</td>
<td>+15 -41 +21 -75</td>
<td>-25 -39 +42 -63</td>
<td>+45 -26 +16 -54</td>
<td>+10 +7 +7 -3</td>
</tr>
</tbody>
</table>

**NOTE:**
- **T** = Tensile, psi
- **E** = Ultimate Elongation, %
- **H** = Hardness, Shore A
- **S** = Strain, % Elongation @ 200 psi Load

**TABLE I. PHYSICAL PROPERTIES OF VULCANIZATES AGED INDOORS TEN YEARS (PERCENT CHANGE FROM ORIGINAL VALUES)**
| Aging Time Periods | SBR | | | | Neoprene | | | | | NBR | | | | | Butyl | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Original | 2040 | 480 | 57 | 105 | 2010 | 350 | 59 | 70 | 1520 | 360 | 63 | 83 | 2420 | 870 | 44 | 101 |
| 1 year | +19 | -23 | +14 | -51 | -20 | -17 | +15 | -43 | +2 | -17 | +16 | -45 | -11 | -3 | +7 | -4 |
| 4 years | +1 | -46 | +26 | -67 | -40 | -49 | +41 | -71 | +8 | -42 | +32 | -70 | -11 | -8 | +30 | -31 |
| 7 years | +18 | -50 | +28 | -71 | -30 | -51 | +41 | -87 | -9 | -58 | +33 | -78 | -8 | -17 | +34 | -52 |
| 8 years | +5 | -50 | +30 | -71 | -34 | -51 | +41 | -83 | -12 | -58 | +35 | -77 | -11 | -17 | +32 | -51 |
| 9 years | +12 | -54 | +30 | -71 | -31 | -57 | +42 | -77 | +5 | -58 | +33 | -77 | -10 | -21 | +39 | -52 |
| 10 years | +7 | -56 | +33 | -73 | -37 | -63 | +49 | -84 | -3 | -61 | +38 | -80 | -7 | -23 | +41 | -55 |

**NOTE:**
- T = Tensile, psi
- E = Ultimate Elongation, %
- H = Hardness, Shore A
- S = Strain, % Elongation @ 200 psi Load
- #S = Strain, % Elongation @ 100 psi Load
TABLE III. STRAIN DATA FOR HEAT AGED VULCANIZATES

(Vulcanizates Aged in an Air Oven @ 158°F) (4)

<table>
<thead>
<tr>
<th>Aging Time Period (Days)</th>
<th>% Retention of Original (Unaged) Value</th>
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</thead>
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### TABLE IV. STRAIN DATA FOR INDOOR AGED VULCANIZATES (4)

<table>
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<tr>
<th>Aging Time Period (Years)</th>
<th>% Retention of Original (Unaged) Value</th>
<th>SBR</th>
<th>Neoprene</th>
<th>NBR</th>
<th>Butyl</th>
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### TABLE V. STRAIN DATA FOR OUTDOOR AGED VULCANIZATES (4)

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<th>Aging Time Period (Years)</th>
<th>% Retention of Original (Unaged) Value</th>
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<td>30</td>
<td>69</td>
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<td>23</td>
<td>23</td>
<td>48</td>
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### TABLE VI. PHYSICAL PROPERTY CHANGE OF COMMERCIAL NITRILE COMPOUNDS - RMA

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<tr>
<th>Storage Age (Years)</th>
<th>Tensile Change (%)</th>
<th>Elongation Change (%)</th>
<th>100% Modulus Change (%)</th>
<th>Hardness Change (points)</th>
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<tbody>
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<td>+3.6</td>
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### TABLE VII. PHYSICAL PROPERTY CHANGE OF COMMERCIAL NEOPRENE COMPOUNDS - RMA

<table>
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<tr>
<th>Storage Age (Years)</th>
<th>Tensile Change (%)</th>
<th>Elongation Change (%)</th>
<th>100% Modulus Change (%)</th>
<th>Hardness Change (points)</th>
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25
### TABLE VIII. PHYSICAL PROPERTY CHANGE OF BUTYL RUBBER COMPOUNDS - RMA

<table>
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<th>Storage Age (Years)</th>
<th>Tensile Change (%)</th>
<th>Elongation Change (%)</th>
<th>100% Modulus Change (%)</th>
<th>Hardness Change (points)</th>
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### TABLE IX. PHYSICAL PROPERTY CHANGE - MIL-P-5516, CLASS B - RMA

<table>
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<th>Tensile Change (%)</th>
<th>Elongation Change (%)</th>
<th>100% Modulus Change (%)</th>
<th>Hardness Change (points)</th>
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<td>+10.0</td>
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<td>+5</td>
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### TABLE X. PHYSICAL PROPERTY CHANGE - MIL-G-5510A AND MIL-P-5315A COMPOUNDS - RMA

<table>
<thead>
<tr>
<th>Storage Age (Years)</th>
<th>Tensile Elongation</th>
<th>100% Modulus Hardness</th>
<th>Hardness Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Change (%)</td>
<td>Change (%)</td>
<td>Change (points)</td>
</tr>
<tr>
<td>1 (1)*</td>
<td>+9.0</td>
<td>-33.0</td>
<td>-</td>
</tr>
<tr>
<td>(2)</td>
<td>+23.0</td>
<td>+6.0</td>
<td>+6</td>
</tr>
<tr>
<td>2 (1)</td>
<td>+11.0</td>
<td>-26.0</td>
<td>-1</td>
</tr>
<tr>
<td>(2)</td>
<td>+23.0</td>
<td>+12.0</td>
<td>+4</td>
</tr>
<tr>
<td>3.5 (1)</td>
<td>+14.0</td>
<td>-20.0</td>
<td>-</td>
</tr>
<tr>
<td>(2)</td>
<td>+21.0</td>
<td>-4.0</td>
<td>+1</td>
</tr>
<tr>
<td>4.5 (1)</td>
<td>+17.5</td>
<td>-37.0</td>
<td>0</td>
</tr>
<tr>
<td>(2)</td>
<td>+18.0</td>
<td>+29.0</td>
<td>+2</td>
</tr>
<tr>
<td>7.5 (1)</td>
<td>+17.0</td>
<td>-41.0</td>
<td>+2</td>
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<tr>
<td>(2)</td>
<td>+16.0</td>
<td>+34.0</td>
<td>+9</td>
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*(1) MIL-G-5510A  
(2) MIL-P-5315A

### TABLE XI. PHYSICAL PROPERTY CHANGE - MIL-P-25732 AND MIL-P-18017 COMPOUNDS - RMA

<table>
<thead>
<tr>
<th>Storage Age (Years)</th>
<th>Tensile Elongation</th>
<th>100% Modulus Hardness</th>
<th>Hardness Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Change (%)</td>
<td>Change (%)</td>
<td>Change (points)</td>
</tr>
<tr>
<td>1 (1)*</td>
<td>-5.1, +1.1</td>
<td>+3.6, -10.0</td>
<td>-4.0</td>
</tr>
<tr>
<td>(2)</td>
<td>+11.0</td>
<td>-10.0</td>
<td>-</td>
</tr>
<tr>
<td>3 (1)</td>
<td>-2.2</td>
<td>-7.5</td>
<td>+14.9</td>
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<td>4.5 (2)</td>
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<td>-13.0</td>
<td>+54.0</td>
</tr>
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<td>+0.2</td>
<td>-12.1</td>
<td>+33.8</td>
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<td>5.5 (2)</td>
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<td>7.5 (2)</td>
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<td>+72.0</td>
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*(1) MIL-P-25732  
(2) MIL-P-18017
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Age</th>
<th>Spec.No.</th>
<th>Tensile (psi)</th>
<th>Elongation (%)</th>
<th>Modulus 100%</th>
<th>Hardness</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>New</td>
<td>MIL-P-5516</td>
<td>1345</td>
<td>203</td>
<td>534</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>5 Years</td>
<td>&quot;</td>
<td>1430</td>
<td>171</td>
<td>693</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>% Change</td>
<td>+6</td>
<td>-15.6</td>
<td>+30</td>
<td>+3</td>
<td></td>
</tr>
<tr>
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<td>New</td>
<td>MIL-P-5516</td>
<td>1485</td>
<td>195</td>
<td>693</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>5.5 Years</td>
<td>&quot;</td>
<td>1520</td>
<td>195</td>
<td>825</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>% Change</td>
<td>+2.3</td>
<td>0</td>
<td>+19</td>
<td>+3</td>
<td></td>
</tr>
<tr>
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<td>MIL-P-5516</td>
<td>1485</td>
<td>222</td>
<td>462</td>
<td>68</td>
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<td></td>
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<td>&quot;</td>
<td>1550</td>
<td>168</td>
<td>775</td>
<td>70</td>
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<td>+5</td>
<td></td>
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<td>69</td>
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<td>185</td>
<td>1025</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>% Change</td>
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<td>-18</td>
<td>+52</td>
<td>+16</td>
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<td>-11</td>
<td>+23</td>
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<td>345</td>
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<tr>
<td></td>
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<td>462</td>
<td>60</td>
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<td></td>
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<td>-6.2</td>
<td>+25</td>
<td>0</td>
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</tr>
<tr>
<td>7</td>
<td>New</td>
<td>MIL-P-5315</td>
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<td>260</td>
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</tr>
<tr>
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<td>&quot;</td>
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<td>230</td>
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<td>71</td>
</tr>
<tr>
<td></td>
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<td>-11</td>
<td>+46</td>
<td>+16</td>
<td></td>
</tr>
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<td>Age</td>
<td>Spec.No.</td>
<td>Hardness</td>
<td>Tensile (psi)</td>
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<td>-------------</td>
<td>------------</td>
<td>----------</td>
<td>---------------</td>
<td>----------------</td>
<td>--------</td>
<td>-------------</td>
</tr>
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<td>75</td>
<td>1558</td>
<td>288</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-3/4 Years</td>
<td>&quot;</td>
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<td>1320</td>
<td>208</td>
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<td></td>
</tr>
<tr>
<td>% Change</td>
<td>&quot;</td>
<td>5</td>
<td>-15</td>
<td>-28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New</td>
<td>&quot;</td>
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<td>6.3</td>
<td>-20.1</td>
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</tr>
<tr>
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<td>-5</td>
<td>-23.1</td>
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<td></td>
</tr>
<tr>
<td>% Change</td>
<td>&quot;</td>
<td>-11</td>
<td>-18.1</td>
<td>-32.4</td>
<td>29.8</td>
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</tr>
<tr>
<td>New</td>
<td>&quot;</td>
<td>8</td>
<td>5</td>
<td>13.8</td>
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</tr>
<tr>
<td>5-3/4 Years</td>
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<td>5</td>
<td>-11.6</td>
<td>-20.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Change</td>
<td>&quot;</td>
<td>-12</td>
<td>7</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New</td>
<td>AMS7274</td>
<td>75</td>
<td>1558</td>
<td>288</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-1/4 Years</td>
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<td>1394</td>
<td>168</td>
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<tr>
<td>% Change</td>
<td>&quot;</td>
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<td>2</td>
<td>-42</td>
<td></td>
<td></td>
</tr>
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<td>&quot;</td>
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<td>6.3</td>
<td>-20.1</td>
<td>3.2</td>
<td></td>
</tr>
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<td>-21.4</td>
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<td></td>
</tr>
<tr>
<td>% Change</td>
<td>&quot;</td>
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<td>-14.1</td>
<td>-32.4</td>
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</tr>
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<td>&quot;</td>
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<td>5</td>
<td>13.8</td>
<td></td>
<td></td>
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<tr>
<td>7-1/4 Years</td>
<td>&quot;</td>
<td>5</td>
<td>-11.6</td>
<td>-20.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Change</td>
<td>&quot;</td>
<td>-12</td>
<td>7</td>
<td>1</td>
<td></td>
<td></td>
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<td>1227</td>
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<td>1.116</td>
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<td>5-1/4 Years</td>
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<td>5.7</td>
<td>1.139</td>
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</tr>
<tr>
<td>% Change</td>
<td>&quot;</td>
<td>5</td>
<td>-27</td>
<td>-10</td>
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<tr>
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<td>1.121</td>
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<td>246</td>
<td>5.5</td>
<td>1.139</td>
<td></td>
</tr>
<tr>
<td>% Change</td>
<td>&quot;</td>
<td>8</td>
<td>-25</td>
<td>0</td>
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</table>

# In addition to normal aging
A=Manufacturer A
B=Manufacturer B
TABLE XIV. EFFECT OF SHELF AGING ON MIL-P-5516 O-RINGS - MARE ISLAND NAVAL SHIPYARD

<table>
<thead>
<tr>
<th>Storage Age (Years)</th>
<th>Ultimate Tensile (psi)</th>
<th>Ultimate Elongation (%)</th>
<th>100% Modulus (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
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<td>First Manufacturer</td>
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</tr>
<tr>
<td>4</td>
<td>1600</td>
<td></td>
<td>140</td>
</tr>
<tr>
<td>5</td>
<td>1590</td>
<td>1570</td>
<td>1560</td>
</tr>
<tr>
<td>6</td>
<td>1630</td>
<td>1570</td>
<td>1610</td>
</tr>
<tr>
<td>7</td>
<td>1550</td>
<td>1550</td>
<td>1580</td>
</tr>
<tr>
<td>8</td>
<td>1560</td>
<td>1590</td>
<td>1560</td>
</tr>
<tr>
<td>Second Manufacturer</td>
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</tr>
<tr>
<td>4</td>
<td>1730</td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>5</td>
<td>1630</td>
<td>1770</td>
<td>1770</td>
</tr>
<tr>
<td>6</td>
<td>1760</td>
<td>1750</td>
<td>1740</td>
</tr>
<tr>
<td>7</td>
<td>1750</td>
<td>1760</td>
<td>1760</td>
</tr>
<tr>
<td>8</td>
<td>1750</td>
<td>1770</td>
<td>1640</td>
</tr>
</tbody>
</table>

A - O-Rings stored in sealed envelopes.
B - O-Rings exposed to air and artificial light.
C - O-Rings exposed to air but light excluded.
<table>
<thead>
<tr>
<th>Aging Time (Years)</th>
<th>SBR</th>
<th>Polyurethane</th>
<th>Silicone</th>
<th>Polyacrylate</th>
<th>Viton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>E</td>
<td>H</td>
<td>C</td>
<td>T</td>
</tr>
<tr>
<td>Original</td>
<td>1500</td>
<td>200</td>
<td>68</td>
<td>41</td>
<td>3200</td>
</tr>
<tr>
<td>1</td>
<td>1500</td>
<td>200</td>
<td>69</td>
<td>42</td>
<td>3000</td>
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<td>1450</td>
<td>180</td>
<td>70</td>
<td>45</td>
<td>3100</td>
</tr>
<tr>
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<td>170</td>
<td>71</td>
<td>44</td>
<td>3400</td>
</tr>
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<td>1425</td>
<td>170</td>
<td>72</td>
<td>38</td>
<td>3450</td>
</tr>
<tr>
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<td>170</td>
<td>72</td>
<td>36</td>
<td>3475</td>
</tr>
<tr>
<td>6</td>
<td>1450</td>
<td>160</td>
<td>72</td>
<td>36</td>
<td>-</td>
</tr>
</tbody>
</table>

**NOTE:**
- T = Tensile, psi
- E = Ultimate Elongation, 
- H = Hardness, Shore A
- C = Compression Set, % - Test conditions not specified
## Table XVI. The Effect of Shelf Storage Life on the Physical Properties of Silicone, Fluorosilicone, and Fluorocarbon Vulcanizates - Rock Island Arsenal

<table>
<thead>
<tr>
<th>Shelf Storage Time (Years)</th>
<th>Tensile Strength (psi)</th>
<th>Modulus at 300% E (psi)</th>
<th>Elongation (%)</th>
<th>Hardness (Shore A)</th>
<th>Strain, NBS, 400 psi (%)</th>
<th>Compression Set 22 hr/74°F (%)</th>
<th>Volume Change 70 hr/302°F ASTM #3 Oil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorocarbon</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Original</td>
<td>2280</td>
<td>1810</td>
<td>380</td>
<td>69</td>
<td>127</td>
<td>38</td>
<td>7</td>
</tr>
<tr>
<td>0.5</td>
<td>2330 (+2)</td>
<td>1660 (-8)</td>
<td>410 (+8)</td>
<td>70</td>
<td>127 (0)</td>
<td>44</td>
<td>6</td>
</tr>
<tr>
<td>1.0</td>
<td>2650 (+16)</td>
<td>1730 (-4)</td>
<td>470 (+24)</td>
<td>72</td>
<td>129 (+2)</td>
<td>48</td>
<td>6</td>
</tr>
<tr>
<td>1.5</td>
<td>2460 (+8)</td>
<td>1680 (-7)</td>
<td>460 (+21)</td>
<td>71</td>
<td>121 (-5)</td>
<td>48</td>
<td>6</td>
</tr>
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<td>1730 (-4)</td>
<td>450 (+18)</td>
<td>70</td>
<td>130 (+2)</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
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<td>1720 (-5)</td>
<td>460 (+21)</td>
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<td>115 (-9)</td>
<td>41</td>
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</tr>
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<td>400</td>
<td>54</td>
<td>106</td>
<td>49</td>
<td>41</td>
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<tr>
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<td>890 (+24)</td>
<td>370 (+8)</td>
<td>57</td>
<td>103 (+3)</td>
<td>49</td>
<td>43</td>
</tr>
<tr>
<td>1.0</td>
<td>1010 (+20)</td>
<td>870 (+21)</td>
<td>380 (-5)</td>
<td>57</td>
<td>101 (-5)</td>
<td>42</td>
<td>42</td>
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<tr>
<td>1.5</td>
<td>970 (+15)</td>
<td>850 (+18)</td>
<td>370 (+8)</td>
<td>54</td>
<td>98 (-8)</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>2.0</td>
<td>1030 (+23)</td>
<td>930 (+29)</td>
<td>350 (-13)</td>
<td>54</td>
<td>100 (-6)</td>
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<td>45</td>
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<tr>
<td>3.0</td>
<td>940 (+12)</td>
<td>870 (+21)</td>
<td>350 (-13)</td>
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<td>99</td>
<td>21</td>
<td>43</td>
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<td>High Strength Silicone</td>
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<td>310</td>
<td>740</td>
<td>50</td>
<td>218</td>
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<td>109</td>
</tr>
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TABLE XXIV. O-RING PHYSICAL PROPERTIES AFTER STORAGE -
MOBILE - MIL-P-5516 - MANUFACTURER B

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<td>11.9</td>
<td>13.3</td>
<td>14.21</td>
</tr>
<tr>
<td></td>
<td>6.14</td>
<td>7.36</td>
<td>7.98</td>
<td>9.20</td>
<td>11.0</td>
<td>11.8</td>
<td>11.50</td>
</tr>
<tr>
<td></td>
<td>6.25</td>
<td>7.50</td>
<td>9.38</td>
<td>10.12</td>
<td>12.4</td>
<td>12.6</td>
<td>13.13</td>
</tr>
<tr>
<td>Median</td>
<td>6.25</td>
<td>7.50</td>
<td>8.64</td>
<td>9.25</td>
<td>11.0</td>
<td>12.3</td>
<td>13.13</td>
</tr>
</tbody>
</table>

**NOTE:** The compression set is expressed as the percentage of the original deflection.
### TABLE XXX. OIL COMMITTEE 0-4 FLUOROCARBON ELASTOMER AGING STUDY

#### Compressed O-Rings (2 each) Room Temperature

<table>
<thead>
<tr>
<th>Property</th>
<th>Time</th>
<th>Compound A</th>
<th>Compound B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile, psi</td>
<td></td>
<td>Lab 1</td>
<td>Lab 2</td>
</tr>
<tr>
<td>Orig.</td>
<td>1940</td>
<td>1690</td>
<td>1640</td>
</tr>
<tr>
<td>1 yr</td>
<td>1950</td>
<td>1690</td>
<td>1670</td>
</tr>
<tr>
<td>2 yrs</td>
<td>1955</td>
<td>1690</td>
<td>1670</td>
</tr>
<tr>
<td>3 yrs</td>
<td>1960</td>
<td>1690</td>
<td>1670</td>
</tr>
<tr>
<td>Ultimate Elong., %</td>
<td></td>
<td>Lab 1</td>
<td>Lab 2</td>
</tr>
<tr>
<td>Orig.</td>
<td>190</td>
<td>190</td>
<td>210</td>
</tr>
<tr>
<td>1 yr</td>
<td>195</td>
<td>195</td>
<td>215</td>
</tr>
<tr>
<td>2 yrs</td>
<td>200</td>
<td>200</td>
<td>220</td>
</tr>
<tr>
<td>3 yrs</td>
<td>205</td>
<td>205</td>
<td>225</td>
</tr>
<tr>
<td>Mod. 100% Flange, psi</td>
<td></td>
<td>Lab 1</td>
<td>Lab 2</td>
</tr>
<tr>
<td>Orig.</td>
<td>730</td>
<td>800</td>
<td>510</td>
</tr>
<tr>
<td>1 yr</td>
<td>800</td>
<td>800</td>
<td>530</td>
</tr>
<tr>
<td>2 yrs</td>
<td>825</td>
<td>780</td>
<td>350</td>
</tr>
<tr>
<td>3 yrs</td>
<td>850</td>
<td>590</td>
<td>760</td>
</tr>
<tr>
<td>Hardness</td>
<td></td>
<td>Lab 1</td>
<td>Lab 2</td>
</tr>
<tr>
<td>Orig.</td>
<td>80</td>
<td>80</td>
<td>75</td>
</tr>
<tr>
<td>1 yr</td>
<td>75</td>
<td>75</td>
<td>74</td>
</tr>
<tr>
<td>2 yrs</td>
<td>78</td>
<td>78</td>
<td>77</td>
</tr>
<tr>
<td>3 yrs</td>
<td>81</td>
<td>81</td>
<td>73</td>
</tr>
<tr>
<td>Comp. Set, %</td>
<td></td>
<td>Lab 1</td>
<td>Lab 2</td>
</tr>
<tr>
<td>Orig.</td>
<td>29.0</td>
<td>31.0</td>
<td>23.5</td>
</tr>
<tr>
<td>1 yr</td>
<td>25.0</td>
<td>23.7</td>
<td>21.7</td>
</tr>
<tr>
<td>2 yrs</td>
<td>26.0</td>
<td>25.0</td>
<td>22.5</td>
</tr>
<tr>
<td>3 yrs</td>
<td>30.0</td>
<td>26.4</td>
<td>23.2</td>
</tr>
</tbody>
</table>

- **Comp. Set, %**
  - 24 hrs at 350°F
  - 30 min. after release
  - 3 days after release

### Notes:
- Compression tester containing 2 O-Rings which had been stored at room temperature for three years was placed in an oven for 24 hrs at 350°F. Set was measured 30 mins and 3 days after O-Rings were removed from the fixture.

### Comp. Set, %
- 24 hrs at 350°F
- 30 min. after release
- 3 days after release
REFERENCES


LITERATURE SURVEY ON THE EFFECTS OF LONG-TERM SHELF AGING ON ELASTOMERIC MATERIALS

Summary Technical Report - November 1965 to November 1966

Bellanca, Carmen L.
Harris, Jay C.

August 1967

54

12

AF 33(615)-1484
7381
738102

AFML-TR-67-235

Materials Applications Division
Air Force Materials Laboratory
Wright-Patterson AFB, Ohio 45433

Literature was surveyed with regard to the effects of long-term storage on the properties of elastomeric compounds. Data showed that most elastomeric compounds aged well. Elongation at break appeared to be the property most commonly affected by age deterioration, although compression set and change in strain also are affected.
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