# STUDY ON SEALING CHARACTERISTICS OF ELASTOMER O-RINGS UNDER LOW TEMPERATURE

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## INTRODUCTION

In the design of the packaging for radioactive materials transport (casks), IAEA's transport regulations require considering, as a temperature condition for materials of the component, a temperature range down to -40℃ on the low temperature side. Considered here as component materials for the cask are cask body materials, shock absorber, and sealing materials forming the containment system, etc. Among these, cask body and shock absorber materials are often evaluated by comparing the materials' propertles ; however, the elastomer O-ring, widely used as a sealing material, may become brittle at low temperatures. Although the material properties of elastomer O-rings (such as the brittle point and tensile strength) are relatively known, many things regarding the elastic changes required for evaluating its sealing performance and design data related with the sealing performance remain unknown. This study considers four kinds of elastomers often employed in the containment system of a cask. Under various low temperature conditions the relation between load and displacement characteristics (spring constant) and that between load and sealing performance are shown as data related with the above points, using temperature as a parameter, to clarify the sealing performance and simultaneously propose points to consider as for low temperature characteristics in designing containment system.

## TEST SPECIMENS

Test specimens were made of the O-rings from each of the four kinds of elastomer listed below. These specimens have the performance advantages and disadvantages listed in Table 1.

Table 1 Characteristics of Specimens

| Elastomer | Symbol | Advantages | Disadvantages |
|---|---|---|---|
| Silicon Rubber | A | Cold resistance and thermal stability | Hydrolyzed |
| EPDM | B | ditto | Not oil-proof |
| CR | C | Weather-proof | Not resistant to chemicals |
| FPM | D | Thermal stability | Not resistant to cold resistance |

## TESTING METHOD

In order to evaluate the mechanical characteristics and sealing performance of these material, the techniques listed in Table 2 were selected and executed.

Table 2 Testing Methods

| Item | Technique | Data to be acquired |
|---|---|---|
| Mechanical Characteristics | Compression restoring test | Spring constant |
| | TR test (temperature retraction test) | Ratio of spring-back |
| | Permanent compression Strain test | Stress relaxation |
| Sealing Performance | Leakage test | Leakage occurrance |

The compression restoring and sealing performance tests were performed on the sealing tester shown in Fig. 1. In addition, the permanent compression strain test was carried out with a specimen set at a certain squeeze rate being held inside the constant-temperature oven shown in Fig. 1. The TR tester shown in Fig. 2 was used to measure the relation between the temperature and the ratio of spring-back. This test was carried out in compliance with the relevant ASTM standards.

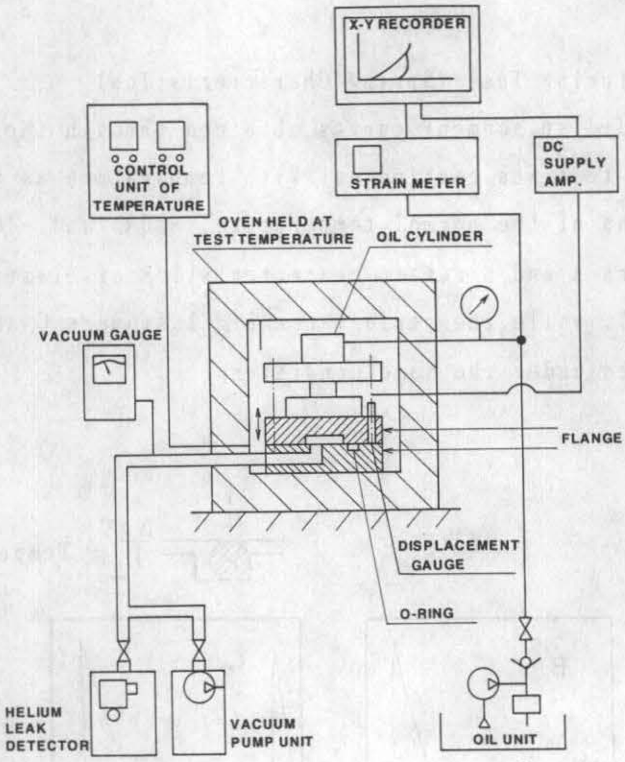


Fig. 1 Seal Tester

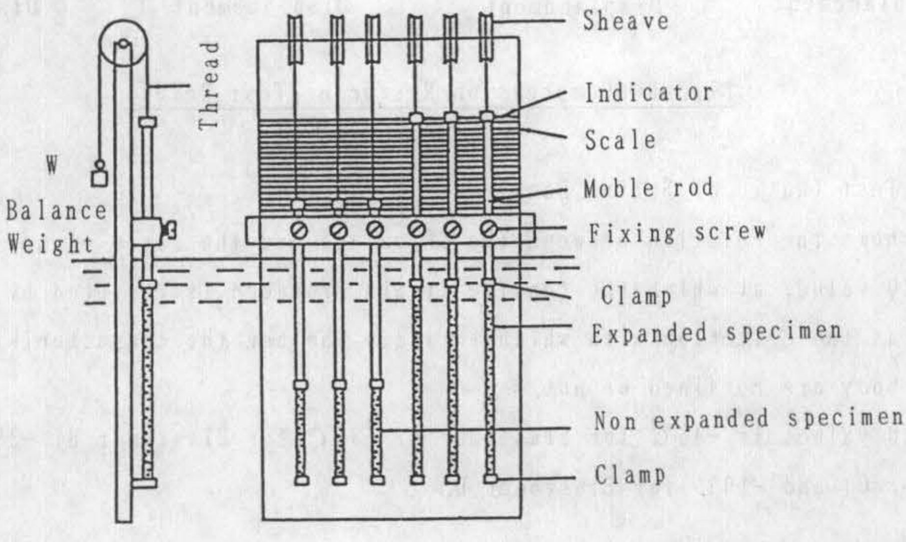


Fig. 2 TR Tester

RESULT OF THE TEST

(1) Compression Restoring Test (Spring Characteristics)

Fig. 3 shows the load-displacement curves obtained through the compression restoring test. The test was carried out with temperature as the parameter; under three conditions of the normal temperature, -20℃ and -40℃. As shown in the graphs, Elastomers A and B retain characteristics of elastic bodies even at temperatures of -40℃, while the performance of Elastomers C and D is significantly degraded under the same condition.

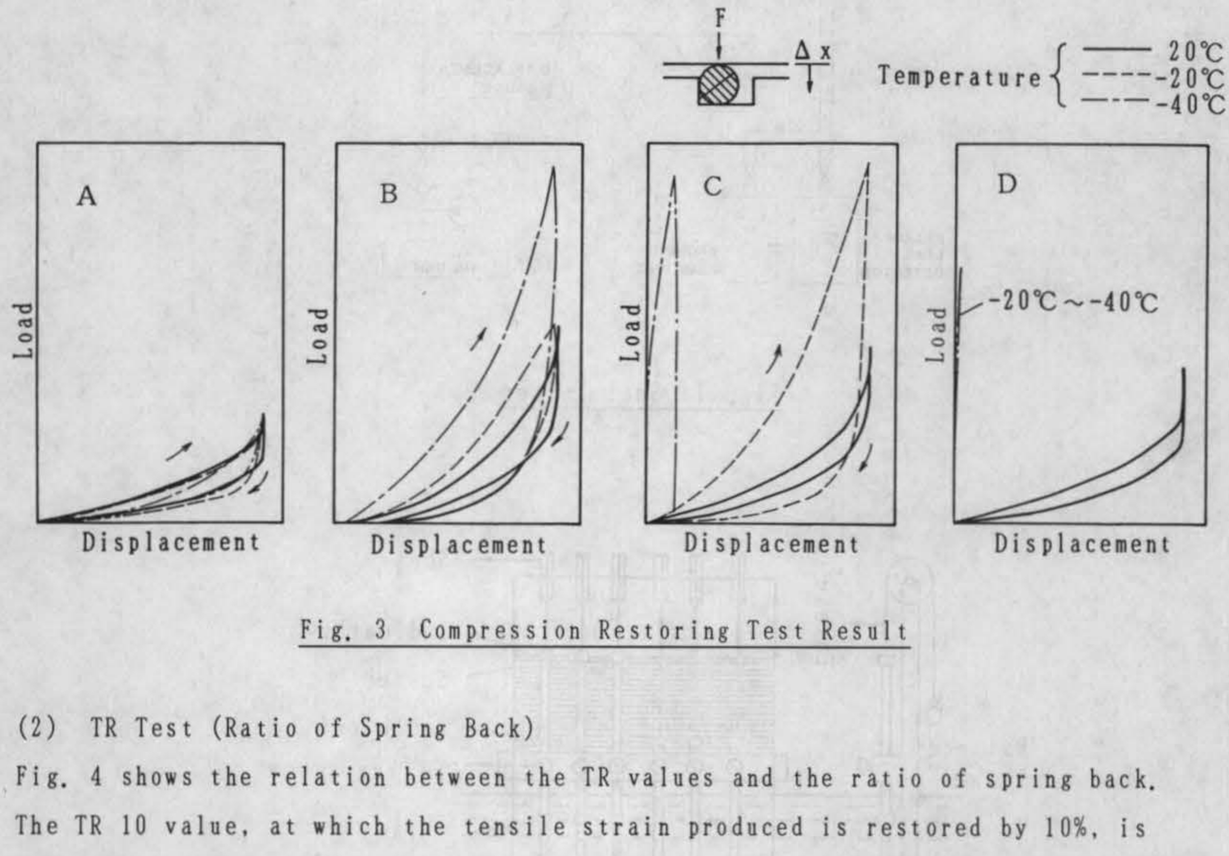


Fig. 3 Compression Restoring Test Result

(2) TR Test (Ratio of Spring Back)

Fig. 4 shows the relation between the TR values and the ratio of spring back. The TR 10 value, at which the tensile strain produced is restored by 10%, is adopted as the criterion with which to judge whether the characteristics as an elastic body are retained or not.

The TR 10 values is -46℃ for Elastomer A, -35℃ for Elastomer B, -39℃ for Elastomer C, and -19℃ for Elastomer D.

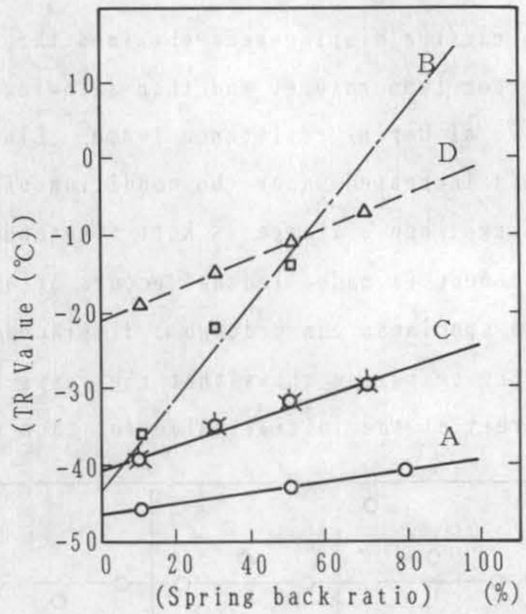


Fig. 4 The Relation between TR Value and Temperature

(3) Permanent Compression Strain Test

Fig. 5 shows the relation between -40℃ exposure duration and permanent compression strain, the values, were measured after returning to room temperature. According to the result, the values are proportional to duration at -40℃ and elastomer D which degrades elasticity most signifcantly has the highest strain and Elastomer A, which retains the characteristics as an elastomer most, has the lowest strain value.

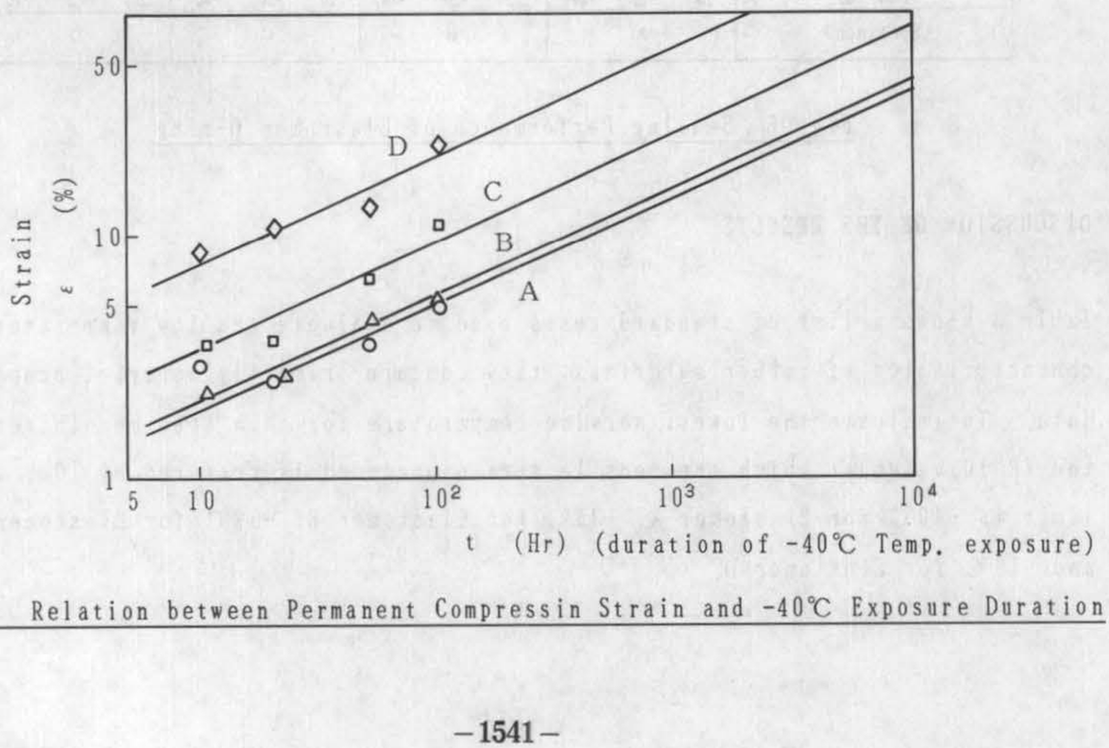


Fig. 5 Relation between Permanent Compressin Strain and -40℃ Exposure Duration

(4) Leakage Test

Fig. 6 shows the leakage causing displacement obtained through cooling down a flange, tightened under room temperature, and then allowing it a restoring displacement and the ratio of O-ring resistance force. Elastomers C and D, in which the spring constants increased under the condition of -40℃ as is shown in Fig. 3, do not allow leakage when a flange is kept tightened. However, just after a restoring displacement is made, leakage occurs at a rate of more than $10^{-6}Pa\cdot m^3/sec$. The other specimens can undergo a displacement of about 30% before leakage occurs. The test also shows that the resistance force of the O-ring remains approximately at the initial value for each of the specimens.

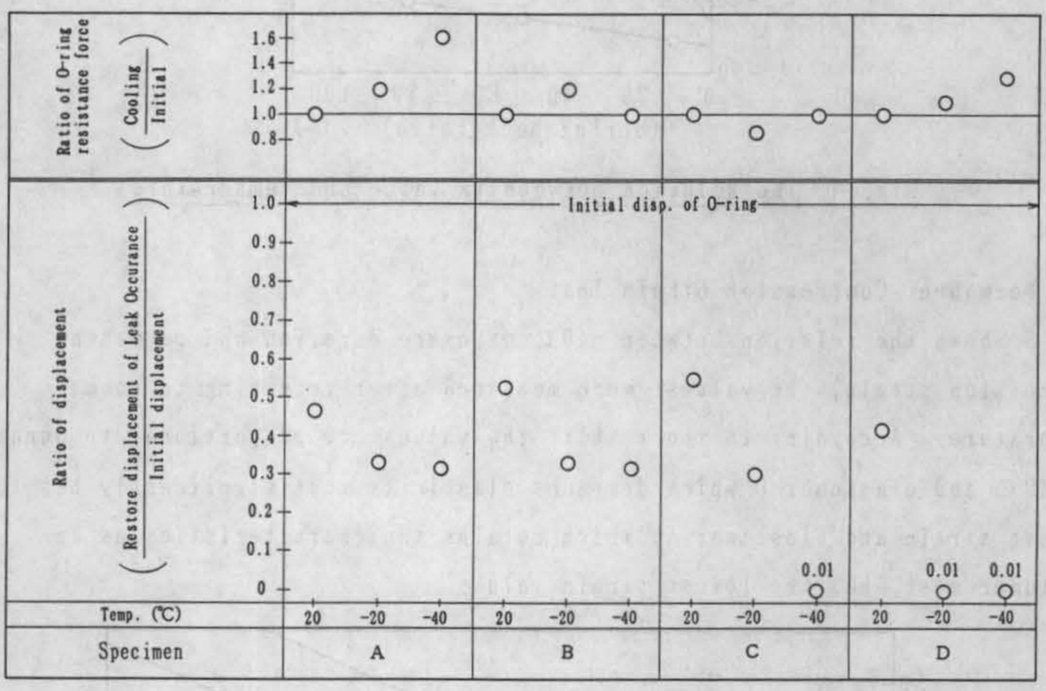


Fig. 6 Sealing Performance of Elastomer O-ring

## DISCUSSION OF THE RESULTS

Table 3 shows a list of standard tests used to evaluate the low temperature characteristics of rubber materials; they contain primarily material property data. To indicate the lowest service temperature for each specimen in terms of the TR 10 value at which the tensile strain produced is restored by 10%, the limit is -40℃ for Elastomer A, -35℃ for Elastomer B, -39℃ for Elastomer C, and -19℃ for Elastomer D.

Table 3 Standard Test for Evaluating Low Temperature Characteristics

| Test | Standard |
|---|---|
| TR Test | ASTMD1329 |
| Cold Resistance Coefficient Test | GOST13808 |
| Impact Brittle Test | JISK6301, GOST7912 |
| Low Temperature bending Test | JISK6380, JISB2401 |

The sealing performance test, however, has revealed that even Elastomers C and D, which significantly degrade characteristics as elastomers under the low temperature condition of -40℃, retain their sealing performance unless restoring displacement occurs. This implies degrading elasticity is not equal to degrading the sealing performance and therefore the sealing performance cannot be evaluated by TR 10 values alone.

The possible reason for this is that, even if an specimen loses its properties as an elastomer, the degradation does not cause a decrease in the resistance force between the O-ring and the flange, and the load is conserved.

It is further revealed that, with Elastomer D which has exhibited the highest value of permanent compression strain among the specimens, the value is at about the same level as the permanent compression strain generated at a temperature of about 150℃ which is below the highest service temperature and therefore the permanent compression strain does not form a determinant in judging the sealing performance at low temperatures.

From the test result described above, it is foreseen that each of the four elastomer types is capable of retaining the sealing performance under the temperature condition of -40℃. And when selecting Elastomers A and B, which have low temperature characteristics nearly equal to normal temperature ones, for use, no special consideration for low temperature use will be necessary; however, when selecting Elastomers C and D, which have significantly degraded properties as elastomers due to change in their characteristics at low temperatures, for use, it is necessary, in designing containment systems consisting of flanges, bolts and sheet surfaces, etc. to provide a system that adapts itself to the loading conditions to be imposed (i.e. impact loads) taking into aeccout of the sealing charactaristics sufficiently.

## CONCLUSIONS

The following conclusions were obtained from the investigation presented here :

(1) If an elastomer does not retain elasticity body under the temperatures of -40℃ but can maintain the resistance force between the O-ring and the flange, it can be considered they are capable of retaining seal.

(2) When selecting sealing materials, they should not only be evaluated with respect to material properties, but should also be tested as described in this report and assessed for deterioration.

(3) The most important point is that the containment system is designed taking into account of the sealing characteristics of selected elastomer sufficient based on the imposed load.

[Reference]

ASTM D 1329-88 Test Method for Evaluating Rebber Property - Retraction at Low Temperature (TR test), 09, 01