Paris Session 2022

Influence of pressure and temperature on O-ring lifetime in highly pressurized dry air

A3

PS2 Q7

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PS2 Question 7

- Q7: The filling pressure of equipment with natural-origin gases is often above 1 MPa. Is there any experience or an estimate on the long-term leakage or other lifetime limiting mechanisms, including mechanical damage, deformation of internal parts, e.g., vacuum interrupters at 0 MPa?

Answer

- **Lifetime limiting mechanism:**

  >> Gas pressure dependencies of the O-ring lifetime

- **Estimate on the long-term leakage:**

  >> Lifetime estimation utilizing annual equivalent temperature

Gas pressure dependencies of the O-ring lifetime

- **Test & Evaluation**
  - ✓ Accelerated tests on compression set, a measure of permanent deformation, of EPDM O-ring in 0.8 MPa dry air (Fig1)
  - ➢ Temperature dependencies of the reaching time to 80% compression set
  - ➢ Comparison with the test results in non-pressurized dry air (Fig2)
- **Results**
  - ✓ Decreasing tendency of lifetime with gas pressure rise
  - ➢ Acceleration of O-ring oxidation

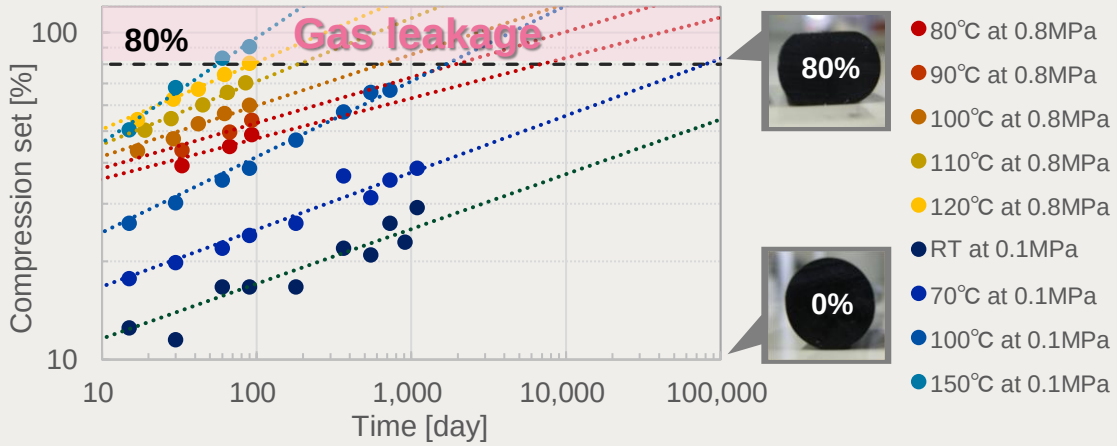

Figure 1 Compression set of EPDM versus time

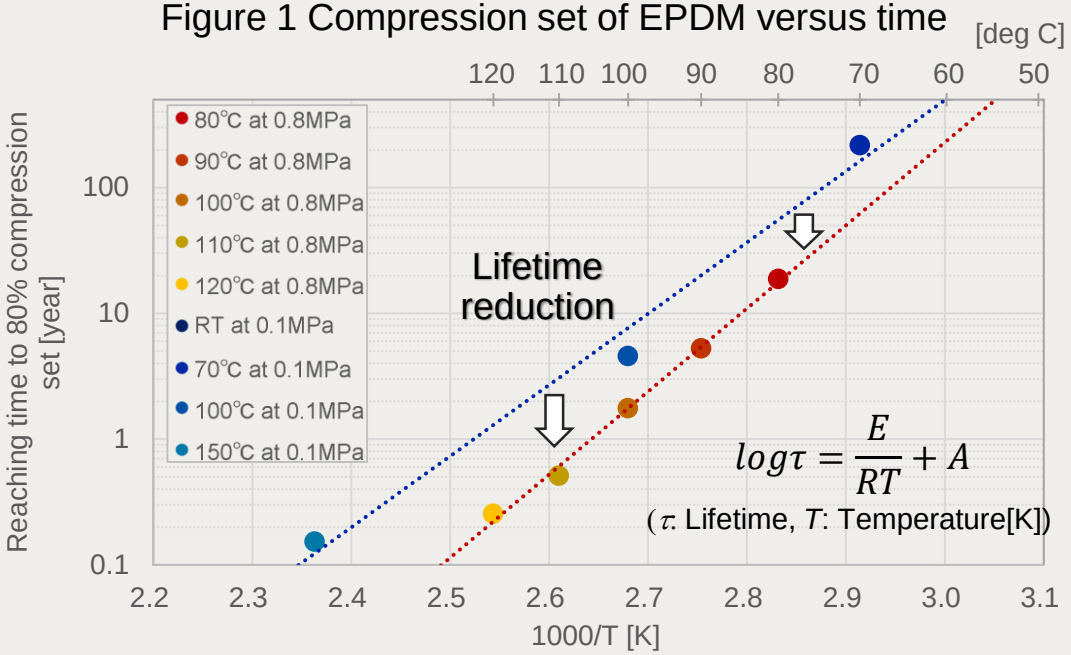

Figure 2 Experimental result of influence of pressure on O-ring lifetime

Lifetime estimation utilizing annual equivalent temperature

- **How to estimate lifetime accurately?**
  - ✓Oxidation reaction rate increases exponentially with temperature

$$k = \frac{1}{\tau} \propto \exp\{\frac{-E}{RT}\}$$

(*k*:Reaction rate, *τ*:Lifetime, *E*:Activate energy, *R*:Gas const, *T*:Temperature)

  - ➢Actual lifetime is represented by annual equivalent temperature (EQ1).

- **Demonstration**
  - ✓Calculation based on the data acquired in a substation (Fig3)
  - ➢Average temperature : 15.1 [deg C]
    Annual equivalent temperature : 17.7 [deg C]
  - ➢20% reduction of lifetime in annual equivalent temperature

$$T_{EQ} = -\frac{E}{R \times \ln[\frac{1}{t_1 - t_0}\int_{t_0}^{t_1} \exp\{-\frac{E}{RT(t)}\}dt]} \quad \ldots(1)$$

(T_{EQ}:Annual equivalent temp, *E*:Activate energy, *R*:Gas const, t_1-t_0:Measurement time, *T(t)*:Temp change in the target area)

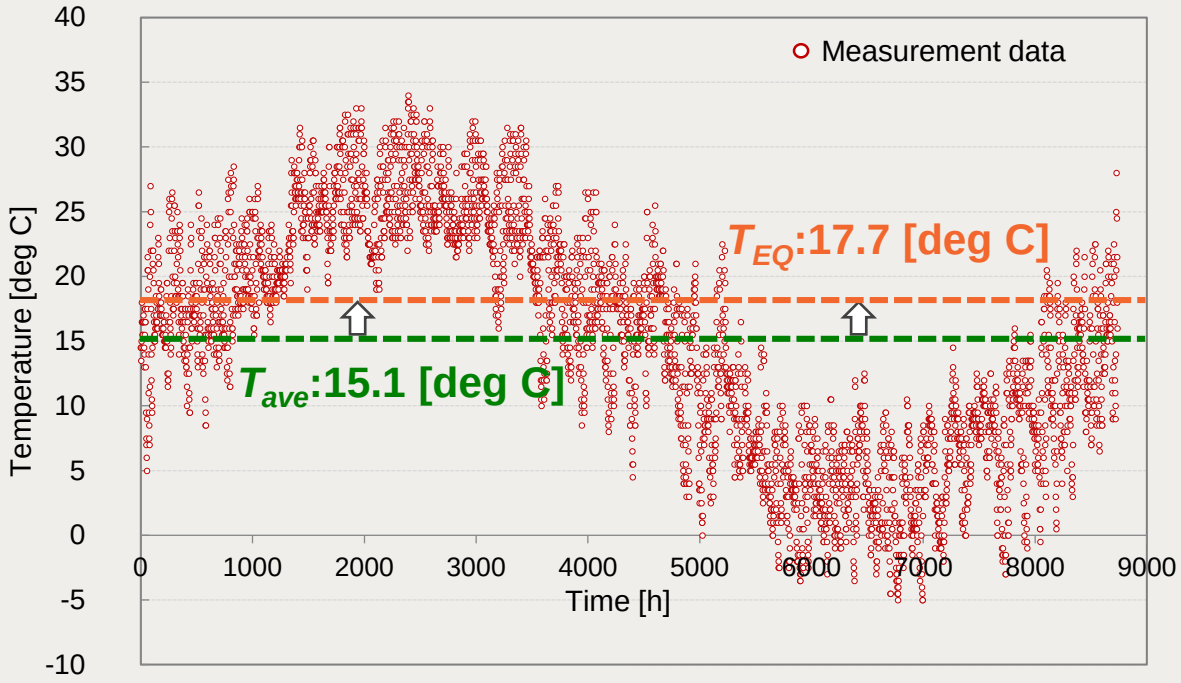

Figure 3 Example of calculation results based on the data acquired in a substation in Japan

Summary: Increasing precision for O-ring lifetime estimation

- **Gas pressure dependencies**

  ✓There is a decreasing tendency of O-ring lifetime with gas pressure rise of dry air due to the progress of oxidation reaction.

- **Utilizing annual equivalent temperature**

  ✓Considering temperature fluctuation at site, equivalent temperature should be used instead of average temperature for more accurate lifetime estimation.

  ->> Lifetime reduction due to the gas pressure rise and increase of temperature fluctuation was confirmed