



Technical Report

Development of fluorocarbon rubber for backup seals of sodium cooled fast breeder reactor

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ABSTRACT

The development of a fluorohydrocarbon rubber compound for static backup seals of 500 MWe, Prototype Fast Breeder Reactor (PFBR) is depicted. Variations of a previously developed Viton A-401C based formulation were subjected to processability tests, accelerated heat ageing in air, mechanical characterization and production trials. Finite element analysis and literature data extrapolation were combined with long term ageing to ascertain the life (minimum 10 years) of chosen formulation in reactor under synergistic influences of 110 °C, 23 mGy/h (γ dose rate) and air considering postulated accidental conditions. Validation of test seals and quality assessment indicate that composition and properties of the validated laboratory compound has been translated effectively to the reactor seals, installed recently in PFBR. The tensile and hardness specimens indicated negligible degradation and exceptional thermo-oxidative stability of the seal compound during ageing (32 weeks at 140/170/200 °C) even though interesting manifestations of cross-link exchange and ionic interactions were observed. Compression set results, showing definite trends of change under ageing and stain, were used in Arrhenius and Williams Landel Ferry equations for realistic life prediction. The development provides a foundation to simplify and standardize the design, development and operation of major elastomeric sealing applications of Indian nuclear reactors based on a few qualified compounds.

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1. Introduction

Fluoroelastomer static backup seal, located behind the inflatable seals (primary barrier), act as secondary leak-resistant barrier (Fig. 1) in the large rotatable plug (LRP) and small rotatable plug (SRP) of the sodium cooled, 500 MWe Prototype Fast Breeder Reactor (PFBR) presently under construction at Kalpakkam. The seal has been developed to withstand continuous exposure of temperature, differential pressure and γ dose rate of 110 °C, 25 kPa and 23 mGy/h in the presence of reactor containment building (RCB) air for a minimum period of 10 years (seal design life) assuming possible occurrence of a maximum differential pressure of 2 MPa at any point of time during seal design life. Large diameter (LRP/SRP seal diameters: \sim 6.4/4.2 m) backup seals based on a hollow, trapezoidal geometry (Fig. 2) and a fluorohydrocarbon rubber (FKM) compound have been manufactured by screw extrusion and installed in PFBR as a result of the development [1–3]. Identification of a suitable generic elastomer and development of appropriate FKM formulation formed a major part of overall effort because of several requirements on seal material performance that had to be addressed simultaneously. This paper summarizes the

material development, presents pertinent results and establishes the long-term suitability of developed compound in reactor environment.

Backup seal, along with the lower inflatable seal, prevent leakage of radioactive argon cover gas to RCB air (and vice versa) through a 5 ± 2 mm wide annular gap between the stationary bearing support ring (BSR) and top and middle ring (TMR) of each plug during normal operation of reactor. Both the fluoroelastomer inflatable seals are engaged during fuel handling condition (backup seal disengaged) to provide dynamic sealing to the annular gap as the TMR is oscillated intermittently. The PFBR operating cycle comprising of 240 days of normal operation and 20 days of fuel handling repeats during reactor life. The capabilities of backup seal to absorb 2 MPa pressure difference during core disruptive accident (CDA) provide additional safeguards as PFBR is designed to absorb such effects without the aid of sealing in annular spaces.

Operating requirements of backup seal demand a soft, low-permeability elastomer with moderate stiffness (modulus), adequate hot tensile properties and high compression set (CS) resistance. Choice of elastomer with the highest feasible CS resistance is preferred as it ensures enhanced safety considering the capability of sealing system to compensate for loss of seal compression (squeeze) during service. The backup seal, held in trapezoidal groove of carbon steel seal holder, is actuated by suitable mechanism to engage/disengage with/from the carbon steel mating sur-

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