Report on radiation influence on EPDM elastomers in Eletta Flow Monitors and Meters

Theoretical paper

Chris Engstrom
Eletta Flow AB, Sweden

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Background

In order to give customers and end-users a formal description on how we look upon the use of EPDM elastomer parts in our Flow Monitors and the lifetime and behavior under harsh condition or used in environment with irradiation, magnetic or radioactive. The products are commonly used in Nuclear Plants and in both Scientific and Medical particle accelerators where they have been installed since early 1960´s. The largest user of the Eletta Flow Monitors is CERN laboratory in Geneva, Switzerland. This paper discusses the following products:

V-series

D-series

S-series

m-series

Definition of the Products

The products are all of the principle of Differential Pressure Flow Monitors and Meters and the scope is from pure mechanical to electromechanical and electronic monitors and meters. However, the working principle is common for all types and only the reading or communication differs in between them. The product was originally designed in the early 1950 and has been manufactured in Sweden in the Eletta factory ever since. The Products has been exported all over the world and only 10% of the production is sold within Sweden. The annual number of produced products are approximately 10 000 units and the total units on the market is + 600 000 units, since the start of the production back in the 1950´s.

Elastomer parts in the product

The Products can be fitted with different types of elastomer in the diaphragm and sealing parts. The diaphragm in the mechanical and electromechanical versions can be

ordered to suit the customers demand or various parameters such as; temperature, pressure, chemical resistance and irradiation. In order to match and cope with the different parameters Eletta Flow Monitors and Meters can be fitted with:

- HNBR elastomer (Hydrated Nitrile)
- EPDM elastomer (Etylen-Propylen-Diene-Methylene)
- FPM (Viton) elastomer (FluorCarbon)

Function of the elastomer parts in the Product

The Eletta Flow Monitors are designed and used for supervising a fluid in a closed conduit and works with a Differential Pressure (DP) principle. The only moving elastomer part in the Eletta Flow Monitors is the wetted diaphragm which is placed in the diaphragm housing. The *diaphragm housing* itself is made of either brass or stainless steel and the *reinforced elastomer diaphragm* is constructed and manufactured according to Eletta´s propriety design. The purpose of the elastomer diaphragm is to transfer the movement created by the differential pressure in the diaphragm housing caused by the obstruction in the pipe and the fluid, gas or liquid. This movement is mechanically transferred through a lever of a propriety design from the wetted side in the diaphragm housing to the dry side inside the control unit housing, where the mechanical transmission converts the movement into a readable flow value, visually or electronically. There is also static O-rings in the design which follows the same chosen material i.e., one of the three materials mentioned above.

The Flow Monitors are pre-calibrated for correct flow measurement and alarm settings in the factory before shipment to customer and then ready to install without any further actions from the customer. In this way, the Monitors can be used a recalibrated safety device supervising the pipe system for irregularities in the flow, which could damage other sensitive parts in the installation.

Important failures due to irradiation

We have looked upon which failures that can occur in general and also in respect to irradiation, which can seriously affect the function of the Flow Monitor:

- Blockage of the flow in the pipe by foreign substance; this will affect the function of the Flow Monitor but will not affect the function when the blockage is removed.

This failure is outside the scope of this paper and hence, this is not a part of our evaluation.

- **A deterioration of the elastomer parts in the design which can cause a leakage of the measured fluid or a gas.**

- A small hole in the casted part of the Monitor and this will cause a leakage. *This failure is outside the scope of this paper and hence, this is not a part of our evaluation.*

- A breakdown of the micro switch/ relay which will stop the alarm function, but the Flow Monitor will still show the actual flow of the fluid or gas in the pipe. *This failure is outside the scope of this paper and hence, this is not a part of our evaluation*.

As the quality system in Eletta Flow AB (manufacturer) is audited and approved according to ISO 9000: 2015 and ISO 14000: 2015, the company is obliged to continuously record and follow all quality issues reported. These records have been following the procedures in the Quality system as per above. The number of sold units are collected from the ERP system which is also recorded and saved in special files in the company computer system.

EPDM elastomers in Eletta Flow Monitors

With regards to the possibility for the EPDM elastomers used in Eletta Flow Monitors to be tested, there has been no actual laboratory test of the full products for irradiation, due to the complex and hazardous environment required for such tests. In order to qualify the EPDM elastomers and to quantify the expected effects and lifetime for these parts, we have to rely on empirical results and experience from the huge installed base around the world. Adding to this, we have searched the academic literatures available where results from both tests and theoretical assumptions combined is included in our report. The only moving elastomer part is the diaphragm which is moving only 5 mm full length of stroke and the rest of the elastomers are static O-rings. The elastomer we are using in application where radiation is present is EPDM, as this is considered to have a good resistant against irradiation. EPDM rubber is classified as radiation-resistant, because EPDM structure

includes in its principal chain totally saturated bonds, and consequently is able to absorb more energy without cracking polymeric chain. EPDM elastomers are considered more radiation resistant than the FPM ones, they absorb a higher amount of dose when placed in a neutron field, due to their larger hydrogen content. “Therefore, the role of EPDM as the best choice for a radiation resistant elastomer and should be reconsidered in applications with intense neutron fields.”

EPDM, is the terpolymer of ethylene, propylene and a nonconjugated diene with residual unsaturation in the side chain.

“In nuclear applications, ethylene propylene diene monomer, EPDM, rubber is the material of choice as gaskets and O-rings due to its radiations resistance. In nuclear applications, ethylene propylene diene monomer (EPDM) rubber is the material of choice as gaskets and O-rings due to its radiation’s resistance developed and characterized for mechanical, thermal, dielectric, and solvent sorption behavior. Spectroscopic and morphological analysis was used to evaluate the compatibility of blends. Due to synergistic effect, the optimal composition of blends with superior mechanical properties and solvent resistance were found to be 60% to 80% EPDM. The optimized blends were irradiated with gamma rays at cumulative doses up to 2 MGy. Based on spectroscopic, morphological, mechanical, thermogravimetric, and sorption properties, blend containing 80% EPDM was found to have superior retention of properties after irradiation[1]”.

The below chart is from the same source as above and show the Tensile properties up to 5MGy and is the result form an actual test in a laboratory.

The Effect of Ionizing Irradiation on the Mechanical Properties of Ethylene Propylene Diene Methylene Rubber (EPDM) [1]

Dose (MGy)	Dose Rate (Gy/H)	Tensile Properties		
		Strength (MPa)	Elongation (%)	Hardness, Shore D
0.000	–	9.4 6 1.0	255.0 6 28.6	15.0 6 0.0
0.500	1.7 3 10^5	7.1 6 1.6	142.0 6 17.2	14.0 6 0.0
1.000	1.7 3 10^5	6.4 6 1.3	121.0 6 20.4	13.0 6 0.0
5.000	1.7 3 10^5	4.2 6 1.2	39.0 6 5.5	14.0 6 0.00.0

Empirical experience

The second part of our evaluation of the irradiation susceptibility and the effects on the EPDM elastomer is based on our experience of being a supplier to the Nuclear

industry where Eletta Flow Monitors has been used and approved in Swedish nuclear company “Vattenfall” and “EdF” in France (both state owned companies), where the products has been used in critical applications since the early 1960´s and with an outstanding performance record. Most of these Monitors are equipped with EPDM elastomers. Our presence in particle accelerator industry has shown very good reliability over long periods both in the laboratory environment as well as in medical. Our Flow Monitors are used by the major corporates in the business, such as IBA (Belgium) and VARIAN (USA) with great confidence. In the world renown CERN laboratory in Geneva, the products as been used for 45 + years and roughly 10 000 units are installed. We have no records of any failures or breakdown due to radiation over the years. In this environment, one can never exact tell how high the irradiation is as well the high magnetic fields are. The Flow Monitors are installed to protect the electro-magnets water cooling system and are placed right next to the beam where high irradiation exists. The Eletta Flow Monitors are installed in most particle accelerators around the world and mainly due to their capability to withstand high levels of irradiation.

Summary

When considering and judging the above discussed theme, one can clearly confirm that the Eletta Flow Monitors has been used in critical and in many cases installations where high surrounding irradiation is present. The end users have clearly, after critical reviews and tests, judged the products after its performance and reliability, empirical evidences and service level from Eletta. We can clearly establish that our Products are well suited to work under high levels of irradiation and harsh environments. Our superior mechanical design secures our unique position in the market where more sophisticated electronic instrument would fail in a very short time. Even though we can not very accurately put a certain number of irradiation capability, it is shown that the above speaks for itself, when showing our Products capability to handle ionizing radiation levels which induce a deterioration of the EPDM properties due to degradative phenomena occurring in the polymer structure. The table showing the Tensile properties show that even if the properties are reduced with higher level of irradiation, the small movement of the diaphragm will probably not be affected and in any way stop the function of the Flow Monitor.

Reference list;

1 = 2017 Wiley Periodicals, Inc. J. Appl. Polym. Sci. **2017**, *134*, 45195.

2 = AIP Conference Proceedings **1779**, 080015 (2016); https://doi.org/10.1063/1.4965559
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