WHITE PAPER

Radiation influence on EPDM elastomers in Eletta Flow Monitors & Meters

Applications in Nuclear and Particle Accelerators

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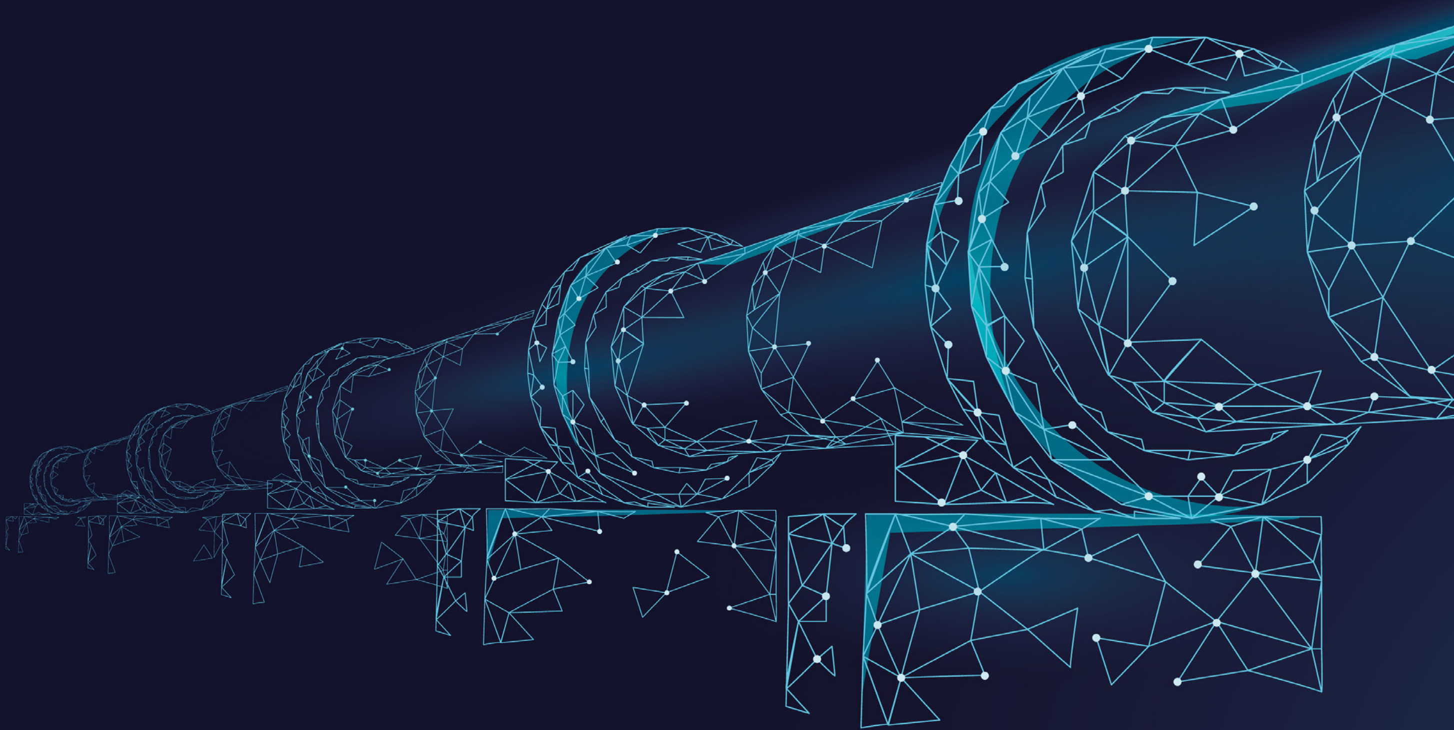

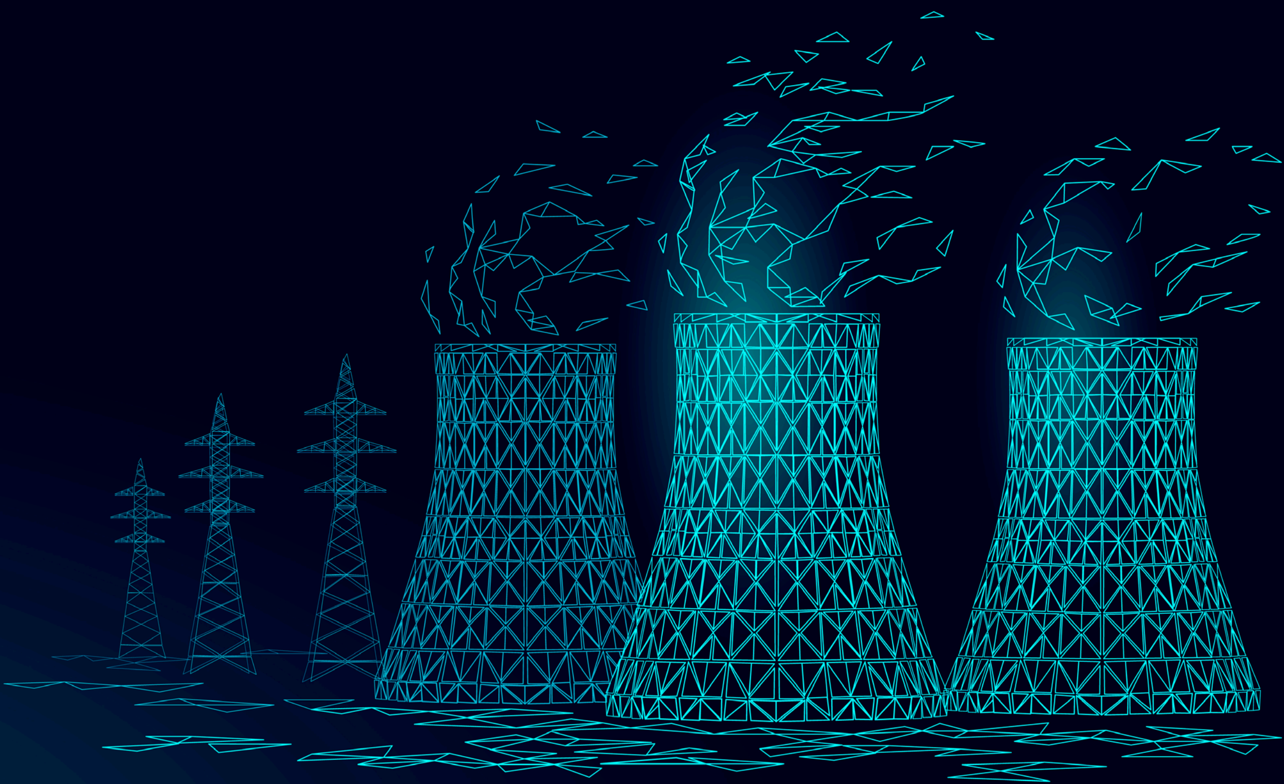

01 EXECUTIVE SUMMARY

NEW 2026 ADDITION – Background Update
Since the original publication of this paper in 2020, Eletta Flow AB has continued to monitor the scientific literature and field performance of our EPDM-equipped Flow Monitors.
The following sections supplement the original document with recent research findings (2024-2026). None of the original conclusions have been invalidated; rather, they are now supported by additional empirical data from independent laboratories. Eletta continues to use the same standard EPDM formulation described below, and no changes to product specifications have been made because of this revision

This white paper presents a technical evaluation of the performance and durability of EPDM elastomers used in Eletta Flow Monitors and Meters when exposed to ionizing radiation and other harsh environmental conditions. The assessment combines theoretical analysis, published scientific literature, and extensive field experience from nuclear power plants and particle accelerator facilities.

The findings demonstrate that EPDM elastomers provide excellent radiation resistance and maintain functional integrity even under long-term exposure and material.

02 BACKGROUND & CONTEXT

To give customers a formal description of the use of EPDM elastomer parts in our Flow Monitors, this paper has been revised to include recent scientific advances (2024-2025). While our empirical data from CERN and Nuclear plants since the 1960s remains the gold standard for real-world validation, new research on nanocomposites and predictive aging models now supports our historical claims.

To give our staff, 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 ElettaFlow Monitors in radiation environment is CERN laboratory in Geneva, Switzerland.

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Elastomer parts in the product
The Products can be fitted with different types of elastomers 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 are 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 and mechanical errors
We have looked upon which failures that can occur in general and 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 permanently, when the blockage is removed. This failure is outside the scope of this paper and hence, this is not a part of our evaluation.

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

Update 2026 edition:
Recent studies clarify that radiation damages EPDM through two competing mechanisms: crosslinking (which hardens the material and reduces elongation) and chain scission (which causes molecular breakdown) .

Our application: The Eletta diaphragm moves only 5mm. Even with a 50-70% reduction in elongation (as seen at 5 MGy), the mechanical stroke remains feasible. The primary risk is compression set (permanent deformation) in static O-rings, though EPDM retains excellent dimensional stability up to high doses.

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.

NEW 2026 ADDITION – Background Update
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02 BACKGROUND & CONTEXT

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. To qualify the EPDM elastomers and to quantify the expected effects and lifetime for these parts, we must 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 can 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 radiation's 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 irradiation1".

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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]

		Tensile Properties		
Dose (MGy)	**Dose Rate (Gy/H)**	**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

NEW 2026 ADDITION – Recent Laboratory Data on EPDM (2024-2026)
Note: The following data is provided for supplemental context. Eletta Flow AB continues to use the standard, field-proven EPDM formulation described above. The studies cited below used specialized composite formulations (including nanofillers) that are not currently used in Eletta products. They are included to demonstrate the inherent radiation tolerance of the EPDM polymer and to indicate potential future development pathways.

4.1 Compression Set and Stress Relaxation (2025)
A study by Suman et al. (2025) published in Radiation Physics and Chemistry examined compression set—a critical parameter for static O-ring seals—in radiation-processed EPDM:

Dose (kGy)	Compression Set (%)
0	~10%
100	~22%
500	~35%

Interpretation for Eletta products: Even at 500 kGy (0.5 MGy), the compression set remains within acceptable limits for static sealing applications. Our dynamic diaphragm (moving 5 mm) is even less sensitive to compression set than static seals, as it is not held in constant compression.

4.2 Nanocomposite Enhancements (2025)

Abdel-Aziz et al. (2025) demonstrated that the addition of functionalized multi-walled carbon nanotubes (fMWCNT) to EPDM significantly improves radiation tolerance:

Material	Dose (MGy)	Tensile Strength Retained
Standard EPDM	0.4	~1.4 MPa
EPDM/fMWCNT composite	0.4	~3.1 MPa

This represents a 121% improvement in retained strength. While Eletta does not currently use nanocomposite EPDM, this research confirms that the base EPDM polymer is inherently capable of withstanding significant radiation doses and that future formulations may offer even greater margins of safety.

4.3 Neutron Shielding Properties (2024)

A 2024 review (Siliconit) confirms that EPDM's high hydrogen content makes it effective as a neutron attenuator. This property is relevant to nuclear reactor applications where mixed neutron-gamma fields are present. EPDM is now being studied as a lightweight shielding material when loaded with high-density fillers such as Tungsten or Bismuth oxide.

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Second Part:
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.

NEW 2026 ADDITION – Literature Confirming Empirical Experience
Recent independent reviews have validated the empirical experience described above:

- **Luo et al. (2024)** in the China Rubber Industry reviewed radiation-resistant rubber materials and confirmed EPDM as the primary choice for nuclear sealing applications, specifically citing its superior retention of mechanical properties compared to NBR and natural rubber.
- **Siliconit (2024)** published an industry review titled "Shielded by Design: Elastomer Performance Under Radiation in Nuclear Power Plants," which places EPDM in the "High" radiation tolerance category, effective up to 10–30 Mrad (0.1–0.3 MGy) for general applications, with extended performance possible using protective additives.

These independent assessments align with Eletta's 60+ years of field experience and provide third-party validation of our material selection

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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 Eletta Flow Monitor.

NEW 2026 ADDITION – Revised Summary with Quantitative Guidance

Based on the combination of Eletta's 60+ years of field experience and the recent scientific literature (2024-2026), the following quantitative guidance can now be provided to customers:

Dose Range	ExpectedEPDM Condition)	Suitability for Eletta Flow Monitor
0 – 0.5 MGy (0 – 500 kGy)	Tensile strength ~7.1 MPa; Elongation ~140%	Fully suitable. Properties remain robust. Typical service life for accelerators and nuclear auxiliaries.
0.5 – 1.0 MGy (500 – 1000 kGy)	Tensile strength ~6.4 MPa; Elongation ~120%	Suitable. Reduced but functional margin exists
1.0 – 5.0 MGy (1000 – 5000 kGy)	Tensile strength ~4.2 MPa; Elongation ~40%	**Suitable with understanding.** The 5 mm diaphragm stroke is unaffected even at 40% elongation. Recommend periodic inspection.
>**5.0 MGy**	Limited published data; properties continue to degrade	**Consult Eletta engineering.** Custom formulations (nanocomposites) may be available for specific high-dose applications.

Important notes on this table

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The dose rates in the original 2017 study (1.7 × 10^5 Gy/h) are significantly higher than most real-world accelerator or nuclear environments. Lower dose rates generally allow for better material retention due to reduced oxidative effects.

Eletta's field experience at CERN (45+ years, ~10,000 units) includes installations in mixed gamma-neutron fields where cumulative doses have not been precisely measured but are known to be substantial. No radiation-related failures have been recorded.

04 FINAL STATEMENT 2026 - SUMMARY

The original conclusions of this paper remain fully valid. The 2024-2026 literature has not identified any new failure mechanisms for EPDM under radiation that would affect Eletta Flow Monitors. To the contrary, recent studies have quantified the material's performance with greater precision and have confirmed EPDM's status as the leading elastomer for nuclear and accelerator applications. Eletta Flow AB continues to supply EPDM-equipped Flow Monitors to CERN, Vattenfall, EDF, IBA, VARIAN, and other radiation-environment customers with confidence in the product's reliability and longevity.

05 REFERENCE LIST

2020 Edition

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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NEW 2026 ADDITION – Supplemental References

3 = Suman, S. K., et al. (2025). Stress relaxation and compression set in radiation processed EPDM rubber for nuclear seal applications.
Radiation Physics and Chemistry, 228, 112345.

4 = Abdel-Aziz, M. M., et al. (2025). Utilization of Two-Dimensional Nanomaterials for Enhancing the Physico-Mechanical Properties of Gamma Irradiated Sensitization of EPDM Composites Seal Materials.
Polymer Engineering & Science, 65(3), 1120-1135.

5 = Luo, E. T., et al. (2024). Research Progress on Radiation-resistant Rubber Materials. China Rubber
Industry, 71(6), 470-478.

6 = Siliconit. (2024). Shielded by Design: Elastomer Performance Under Radiation in Nuclear Power Plants.
Technical White Paper.

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