Materials for use in nuclear applications

Issue 2
Materials development

With over 40 years of service to the nuclear sector, our materials and products are used across a broad range of applications including:

- Fuel processing and handling
- Power generation
- Waste processing
- Transportation and storage

Delivering the highest levels of performance for critical applications is at the heart of everything we do.

James Walker supplies only the highest integrity materials and specialised fluid sealing products to the nuclear industry. Our capabilities are firmly based on our knowledge of the processes involved, their highly specialised sealing requirements, plus the need for exacting quality control and assurance regimes.

James Walker is at the forefront in the development and application of high performance elastomers and engineering plastics. In addition to working with industry standard materials and customers’ own proprietary materials, our Materials Technology Centre is continually working on new formulations to meet customers’ specific operational parameters and to advance our own product ranges.

The result is materials for sealing related products that work efficiently and for longer at extremes of temperature and pressure, with improved resistance to chemicals, abrasion, or ionising radiation.

We are always willing to partner with equipment manufacturers and operators of nuclear facilities to develop, prototype and evaluate materials and/or specific components for ionising radiation resistance duties.

Behind the brand

James Walker also holds a respected reputation as a leading force in the application of materials technology to provide effective solutions to operational issues in critical applications. Based on our unrivalled experience, we precisely match materials, product design and component manufacturing methods to meet customers’ exact specifications and operational requirements.
Shieldseal materials are James Walker’s proprietary materials specifically designed to resist ionising radiation. Their change in physical properties has been monitored over time with gamma radiation to prove compression-set resistance and long service life.

**Shieldseal ® Range**

**Shieldseal ® 663** — a highly-developed EPDM-based elastomer of nominal 80 IRHD for moulded components such as ‘O’ rings. This material has been subjected to extensive radiation/ageing testing to replicate a 40-year lifespan through independent third party testing which demonstrated that Shieldseal 663 significantly outperforms existing industry standard materials. PMUC (17-0383) approved for use in French nuclear plants.

**Shieldseal ® 664** — a further extension of the Shieldseal 663 compound, developed for extrusion manufacturing and use where a softer, more pliable compound is required. With a nominal 65 IRHD hardness, this material is particularly suitable for products such as inflatable seals or door seals. The compound has been subjected to extensive radiation/ageing testing and results show an indicated life-span in excess of 30 years.

**Shieldseal ® 661** — EPDM-based elastomer for liquid and gas sealing in the presence of ionising radiation, where only low closing forces are available. Nominal hardness 55 IRHD.

**Shieldseal ® 662** — EPDM-based elastomer for general applications where ionising radiation is present. Nominal hardness 70 IRHD.

**Shieldseal ® 621** — nitrile elastomer (NBR) designed for radiation resistance. Also excellent resistance to mineral oils, water/glycol hydraulic fluids, and a wide range of chemicals. Nominal hardness 60 IRHD.

**Behind the brand**

Formulating and compounding our own materials gives us total control and traceability through every stage of the manufacturing process.
Shieldseal®
663

**EPDM elastomer with nuclear application life of up to 40 years**

### General properties
Specifically formulated to offer a long service life of up to 40 years in applications where ionizing radiation is present, particularly where the elastomer is in contact with:
- Air
- Hot water
- Steam

This elastomer is also suitable for long-term contact with a wide variety of media associated with nuclear waste, including:
- Dilute acids and alkalis
- Ketones
- Lower alcohols
- Silicone oils and greases

### Leachable ion content
Shieldseal 663 contains a very low level of leachable ions such as Cl− and SO₄²⁻, to ensure that items made of this material do not contribute to corrosion in metalwork.

Water soluble contents of sulphate and chloride are at levels below 3ppm.

### Radiation/thermal resistance
Third-party tests carried out in accordance with international standards show that Shieldseal 663 has good generic radiation resistance up to a dose of 1600kGy in radiation conditions that include elevated temperatures up to 70°C. Thermal pre-ageing of the samples did not significantly alter the end-of-life ageing characteristics.

### Third-party testing by AMEC
Samples of initially un-aged and thermally pre-aged Shieldseal 663 from two different batches were irradiated at a dose rate of 1kGy/h up to 1000kGy in a Co-60 irradiation facility. A number of samples were also irradiated at 70°C to assess synergistic effects.

Samples were then exposed to a further 600kGy, at room temperature, to simulate additional radiation from a Design Basis Event (DBE) such as a loss of coolant accident (LOCA).

Levels of degradation were monitored periodically during radiation/thermal ageing by compression set measurement of button samples. Tensile test samples were aged in the same manner and tested at James Walker Technology Centre for hardness, elongation at break, and tensile strength.

Mechanical testing of aged Shieldseal 663 dumbbell samples showed that, overall, the hardness, elongation at break and tensile strength for both the initially un-aged and the thermally pre-aged samples were similar for each test condition.

#### Elongation at Break test results
Showed that the generally accepted end-of-life condition, defined as 50% elongation at break, was reached at a dose of 1600kGy. (Typical elongation at break value for an un-aged, un-irradiated sample of Shieldseal 663 is 200%.)

#### Compression set test results
These showed that the generally accepted end-of-life value of 90% was reached at 1600kGy. Irradiation at 70°C made little difference to the end-of-life point.

### MECHANICAL PROPERTIES (TYPICAL)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HARDNESS</strong> (nominal):</td>
<td>80 IRHD.</td>
</tr>
<tr>
<td><strong>TENSILE STRENGTH:</strong></td>
<td>18 MPa.</td>
</tr>
<tr>
<td><strong>ELONGATION AT BREAK:</strong></td>
<td>200%</td>
</tr>
<tr>
<td><strong>COMPRESSION SET</strong> (70h @ 125°C):</td>
<td>10.5%</td>
</tr>
</tbody>
</table>

### TEMPERATURE CAPABILITY

- **Min**: -40°C
- **Max**: +25°C constant
- **Max**: +150°C intermittent

Can survive very short exposures to higher temperatures (consult James Walker)

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Shieldseal®
664

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**Third party testing**

Test regimes & standards

Shieldseal 664 has been subjected to rigorous environmental qualification (EQ) to ensure that it can function efficiently as a fluid sealing material within a nuclear power plant throughout the plant’s 40-year working life.

There are two main approaches for attaining EQ. The first follows IEEE 383 and IEC 60780 standards, that subject polymeric components to sequential thermal and radiation ageing. The French RCC-E standard outlines the second approach, that assesses the potential for any synergistic effects by simultaneous thermal and radiation ageing.

**Third party testing by AMEC**

Samples of initially un-aged and thermally pre-aged Shieldseal 663 from two different batches were irradiated at a dose rate of 1kGy/h up to 1000kGy in a Co-60 irradiation facility. A number of samples were also irradiated at 70°C to assess synergistic effects.

Samples were then exposed to a further 600kGy, at room temperature, to simulate additional radiation from a Design Basis Event (DBE) such as a loss of coolant accident (LOCA).

Levels of degradation were monitored periodically during radiation/thermal ageing by compression set measurement of button samples. Tensile test samples were aged in the same manner and tested at James Walker Technology Centre for hardness, elongation at break, and tensile strength.

Mechanical testing of aged Shieldseal 663 dumbbell samples showed that, overall, the hardness, elongation at break and tensile strength for both the initially un-aged and the thermally pre-aged samples were similar for each test condition.

**Elongation at Break test results**

Showed that the generally accepted end-of-life condition, defined as 50% elongation at break, was reached at a dose of 1600kGy. (Typical elongation at break value for an un-aged, un-irradiated sample of Shieldseal 663 is 200%.)

**Compression set test results**

These showed that the generally accepted end-of-life value of 90% was reached at 1600kGy. Irradiation at 70°C made little difference to the end-of-life point.

**Shieldseal® 664** — is a further development of the Shieldseal 663 compound, retaining many of the same performance characteristics. This compound is suited to extrusion manufacturing, moulding and mould joining operations and use where a softer, more pliable compound is required. With a nominal 65 IRHD hardness, this material is particularly suitable for products such as inflatable seals or door seals.

Shieldseal 664 has also been subjected to extensive radiation/ageing testing and results show an indicated life-span in excess of 30 years. The generally accepted end-of-life condition, defined as 50% elongation at break, was reached at a dose of 1200kGy. As with Shieldseal 663, thermal pre-ageing of the samples did not significantly alter the end-of-life ageing characteristics.

Soluble chloride and sulphur are less than 20ppm each for Shieldseal 664, well below the levels required for PMUC approval.
In addition to our own compounds and materials that we have developed for customers, James Walker has a long history of expertise in processing industry standard materials and customer specific materials such as EPDM 30H.

When selecting an elastomer for duties with ionising radiation, it is important to consider other factors in addition to radiation resistance. For example, the elastomer should also be evaluated for physical robustness, chemical compatibility and resistance, and temperature performance in the operational environment.

We regularly compound and/or mould the following elastomers for nuclear duties. A number of these materials are specific to particular customers, as indicated, and cannot otherwise be supplied without their authority.

### Nuclear industry standard elastomers

| Nitrile (NBR) | 18L — nitrile elastomer (NBR): a Sellafield Ltd material  
| Foxglove — nitrile elastomer (NBR): an EDF material  
| PB70 — nitrile elastomer (NBR) of nominal 70 IRHD  
| PMUC approved for use in French nuclear power plants  
| PB80 — nitrile elastomer (NBR) of nominal 80 IRHD  
| PMUC approved for use in French nuclear power plants  

### Silicone (VMQ)

| Lily — silicone elastomer (VMQ): an EDF material  
| LR6920 — silicone elastomer (VMQ) for critical applications: a JW material used for products for EDF  
| LR6935 — silicone elastomer (VMQ) for non-critical applications: a JW material used for products for EDF  
| Poppy range — silicone elastomer (VMQ): an EDF range of materials  
| SIL80/5 — silicone elastomer (VMQ)  

### Ethylene-propylene (EPM/EPDM)

| EP18/H/75 — ethylene propylene elastomer (EPM) of nominal 75 IRHD: PMUC approved for use in French nuclear power plants  
| EP21/E/80 — ethylene propylene elastomer (EPDM) of nominal 80 IRHD: PMUC approved for use in French nuclear power plants  
| EPDM 30H — ethylene propylene elastomer (EPDM): a Sellafield Ltd material  

### Fluoroelastomers (FKM)

| Daisy range — fluoroelastomer (FKM): an EDF range of materials  
| FR10/70(V) — Viton® based fluoroelastomer (FKM) of nominal 70 IRHD Successfully tested to performance levels in excess of PMUC requirements.  
| LR5602/65 — Viton® based fluoroelastomer (FKM) specifically formulated by James Walker for use in high-integrity Magnox nuclear transportation flask seals.  

Alternative materials and engineering capabilities

In addition to manufacturing seals and components in Shieldseal and proprietary industry nuclear elastomer materials, James Walker also offers expertise in engineering plastics and exotic alloys.

Expertise in design, engineering and manufacture of sealing systems for critical applications;

- In-house materials and product testing
- CAD and FEA capabilities for design validation
- In-house tooling design and manufacture
- Rubber to metal bonding
- Precision machining of exotic alloys
- Moulding and machining of engineered plastic materials
- Design, manufacture and assembly of multi-component / multi-material products and sub-assemblies

James Walker is also experienced in the development and application of advanced thermoplastics and thermosets.

Our in-house facilities cover extruding, moulding, monomer casting, hot casting, injection moulding, and precision machining. Using these we can produce runs of one-off to batches of thousands.

Component sizes range from a few millimetres, to in excess of 2.5m diameter, with large items weighing up to 1000kg.

In addition to our own range of Devlon® polymers, other materials available include;

- ABS
- Acetal — homopolymer and copolymer
- PEEK™
- Polyamides/nylons — including plain, filled, reinforced and high molecular weight grades
- Polycarbonate
- Polystyrene — foam and high density
- Polyurethanes — including thermoset
- PTFE — virgin and filled
- PVC
- Rubber — thermoplastic grades
- UHMWPE — plain and filled grades of ultra-high molecular weight polyethylene

Trademark acknowledgements

James Walker acknowledges the following trademarks as mentioned in this guide. All other names bearing the ® symbol are trademarks of James Walker.

PEEK™ Victrex plc
Viton® The Chemours Company
Health warning: Health warning: If PTFE or fluoroelastomer (eg, FKM, FFKM, FEPM) products are heated to elevated temperatures, fumes will be produced which may give unpleasant effects, if inhaled. Whilst some fumes are emitted below 250°C from fluoroelastomers or below 300°C from PTFE, the effect of these temperatures is negligible. Care should be taken to avoid contaminating tobacco with particles of PTFE or fluoroelastomer, or with PTFE dispersion, which may remain on hands or clothing. Safety Data Sheets (SDS) are available on request.

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To ensure you are working with the very latest product specifications, please consult the relevant section of the James Walker website: www.jameswalker.biz.