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CONDUCT OF MAINTENANCE (P950)
OPERATIONS AND MAINTENANCE MANUAL
OPERATIONS & MAINTENANCE CRITERION

TITLE: POLYMER SEALS IN RADIOLOGICAL SERVICE

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DUSA CLASSIFICATION STATEMENT

The information contained in this document conforms to the official definition (including its specific exclusions) of the Construction and Facilities Engineering (CONST) Designated Unclassified Subject Area (DUSA), therefore it is exempt from classification and sensitive information review requirements.

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RECORD OF REVISIONS

Revision No.	Date	Description
0	03/30/01	Initial Issue – Incorporates Lessons Learned from 3/7/1995 to 7/24/2000.
1	9/2/10	Added several materials to Table 6.2.1, Added several new references for radiation damage information.

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CRITERION 428

POLYMER SEALS IN RADIOLOGICAL SERVICE

1.0 PURPOSE

The purpose of this criterion is to establish the minimum requirements and best practices for maintaining polymeric seals in radiological service.

This document addresses the requirements of P 315, *Conduct of Operations Manual*, and P 950, *Conduct of Maintenance*, by defining the minimum operations and maintenance criteria for structures, systems, and components that it covers. The criterion lists requirements that are based on codes, standards, contract commitments, lessons learned, or business case. It also lists recommendations based on industry practices, operational experience, or business case. Guidance for implementation of the requirements and recommendations is also provided.

2.0 SCOPE

The scope of this criterion is to address preventive maintenance of polymer (e.g., Teflon) seals when they are exposed to cumulative levels of radiation of 10^4 rads or greater and provide a barrier to confine hazardous materials.

The LANL complex has approximately 18 nuclear facilities and 59 radiological facilities. Each of these facilities uses seals on valves, pipe/tubing joints, and rotating shafts.

This criterion does not address corrective maintenance actions required to repair or replace equipment. Glovebox gloves are excluded from the scope of this criterion.

3.0 ACRONYMS AND DEFINITIONS

3.1 Acronyms

AR	Administrative Requirements
CFR	Code of Federal Regulations
CMMS	Computerized Maintenance Management System
EPDM	Ethylene Propylene Diene Monomer
O&M	Operations and Maintenance
PP&PE	Personal Property and Programmatic Equipment
RAD	Radiation Absorbed Dose
RP&IE	Real Property and Installed Equipment
SSC	Structures, Systems and Components
TFE	Polytetrafluoroethylene (e.g., Teflon™) (PTFE)

3.2 Definitions

Elastomer- A polymeric material, such as a synthetic rubber or plastic, which at room temperature can be stretched under low stress to at least twice its original length and, upon immediate release of the stress, will return with force to its approximate original length.

Polymer- A substance made of giant molecules formed by the union of simple molecules (monomers).

Rad- A unit of absorbed dose equal to 100 ergs/g.

Seal- Device for closing a gap or making a joint fluid tight.

Seal, Dynamic- Sealing between surfaces that have relative movement.

Seal, Static- Sealing between surfaces that do not move relative to one another.

Teflon- General trademark of the Du Pont Company for its fluorocarbon polymer.

4.0 RESPONSIBILITIES

4.1 MSS-Division Leader (MSS-DL)

Receives and approves or rejects, in conjunction with the AHJ, requests for variances from this criterion. Maintains the record of decision for all variance requests.

4.2 MSS- Maintenance Programs (MSS-MP)

Responsible for the technical content, monitoring the applicability and the implementation status of this Criterion. MSS-MP will assist organizations that are not applying or meeting implementation expectations or will elevate concerns to the appropriate level of LANL management.

4.3 Facility Operations Director (FOD)

Responsible for implementation of this O&M Criterion for identified systems/equipment within their facility boundaries.

4.4 Operations Manager (OM)

Responsible to the FOD for implementing operation portions of this Criterion and for coordinating transfer of systems/equipment to the Maintenance Manager for maintenance activities. The OM with concurrence of the FOD will prioritize implementation within budget allocations.

4.5 Maintenance Manager (MM)

Responsible to the FOD and the MSS-Division Leader for implementing the maintenance portions of this Criterion and for coordinating the transfer of systems/equipment to the Operations Manager at the conclusion of maintenance activities. The MM with concurrence of the FOD will prioritize implementation within budget allocations.

4.6 Authority Having Jurisdiction (AHJ)

The AHJ is the Point of Contact for the Mechanical Chapter of the LANL Engineering Manual. The AHJ is responsible for providing decisions on specific technical questions regarding the systems or equipment relevant to this criterion.

5.0 PRECAUTIONS AND LIMITATIONS

5.1 Precautions

This section is not intended to identify all applicable precautions necessary for implementation of this Criterion. However, all applicable precautions should be contained in the implementing procedure(s) or work control authorization documents. The following precautions are intended only to assist the author of a procedure or work control document in the identification of hazards and precautions that may not be immediately obvious.

5.1.1 Integrated Work Document

Follow an approved Integrated Work Document when inspecting or replacing irradiated seals.

5.2 Limitations

The intent of this Criterion is to identify the minimum requirements and recommendations for structures, systems, and components (SSCs) operation and maintenance across the Laboratory. Each Criterion user is responsible for the identification and implementation of additional facility specific requirements and recommendations based on their authorization basis and unique equipment and conditions, (e.g., equipment history, manufacturer warranties, operating environment, manufacturer O&M requirements and guidance, etc.)

Nuclear facilities and moderate to high hazard non-nuclear facilities will typically have additional facility-specific requirements beyond those presented in this Criterion. Nuclear facilities should implement the requirements of DOE Order 433.1B, *Maintenance Management Program for DOE Nuclear Facilities* as the minimum programmatic requirements for a maintenance program. Additional requirements and recommendations for SSC operation and maintenance may be necessary to fully comply with the current DOE Order or the Code of Federal Regulations (CFR) as applicable.

Nuclear facilities, certain high hazard facilities and explosives facilities may have additional facility specific requirements beyond those presented in this Criterion which are contained in the Documented Safety Analysis (DSA), Technical Safety Requirements (TSRs), or facility safety plans, as applicable.

Because of the damage caused by radiation, polymeric seals have limited value in high radiation applications. Detailed polymer and metal seal application information can be found in the Facility Engineering Manual, Chapter 6.

6.0 REQUIREMENTS

Minimum requirements for all users are specified in this section. Requested variances to these requirements shall be prepared and submitted to MSS-MP for review and approval. The MSS Division Leader approves or denies variances. The Criterion users are responsible for analysis of operational performance and SSC replacement or refurbishment based on this analysis. Laws, codes, contractual requirements, engineering judgment, safety matters, and operations and maintenance experience drive the requirements contained in this section.

Note: Discovery of SSC with a degraded or non-conforming condition is a triggering input to the Operability Determination and Functional Assessment process defined in AP-341-516, *Operability Determination and Functionality Assessment*. Degraded or non-conforming conditions include, but are not limited to, failed equipment or components, unsatisfactory readings, code or standard violations and fire protection impairments. Personnel performing tests or inspections under this O&M Criterion are not responsible nor authorized to perform the Operability Determination. Any degraded or non-conforming condition discovered under this O&M Criterion shall be communicated to the FOD Representative for input to the AP-341-516 process. While that process may not apply in Low Hazard Non-Nuclear and Office facilities, the same concept applies. The FOD organization is responsible to determine the response (taking equipment out of service, establishing fire watches, limiting operations, etc.) to SSC degraded and non-conforming conditions.

6.1 Operations Requirements

6.1.1 Graded Approach

A graded approach shall be used for operations with polymeric sealing materials that are utilized in radioactive environments. A conservative estimate shall be made of the accumulated dose that will be incurred on the component during its operating lifetime in the radiation environment. If the conservative estimate of the dose is less than one half of the damage threshold for a material that provides a safety barrier whose failure could result in the release of radioactive contamination, then no inventory of the item is required and no actions other that routine maintenance and replacement of the item is required.

If the polymer sealing material used in a process operation does not provide a direct safety barrier, or the conservative estimate of the accumulated dose over the components intended lifetime is less than the damage threshold, then no further actions are required except the execution of the routine maintenance program.

For polymeric sealing materials that provide a safety barrier and the estimate of the accumulated dose exceeds one half of the damage threshold or polymeric sealing materials in process applications where the estimated dose exceeds the damage threshold, then a more extensive program of inventory, tracking, and management is required. All

affected polymeric components shall be inventoried and a database of these components shall be maintained. Methods shall be implemented for the determination of the length of suitability of the material for service. Methods should incorporate a direct measurement of the radiation if possible. Where a direct measurement of the dose is not possible other methods, such as function testing, to determine that the continued integrity of the barrier material shall be implemented.

In situations where high doses are potentially incurred, it is best practice to provide multiple barriers to minimize the incurred dose. This includes items such as filters on extraction lines between the glovebox and a polymeric sealing material in a valve or coverings and coatings for other sealing surfaces.

Basis: Seals that could fail and not lead to unacceptable releases are outside of the scope. Notice 51 requires identification of Teflon because it was the material that failed in the ball valve in the 3/2000 TA-55 incident; yet, a similar failure could occur with any polymer as they all sustain damage due to radiation; however, their resistance to radiation damage may be such that 104 in air is too low a threshold for concern.

6.2 Maintenance Requirements

6.2.1 Monitoring and Replacement

Seals and sealing material that are inventoried and have accumulated a dose in excess of one half of the damage threshold shall have a program in place to monitor and ensure their continued performance. It is the best practice to replace materials before they have reached the accumulated dose to cause a 25% degradation in material properties or an accumulated radiation dose of 3.7×10^4 rads for Teflon. The damage thresholds for some other polymeric materials are shown in Table 6.2-1.

The dose rate (106 rad/hr) is relatively high for the data in this table. Depending on the dose rate, temperature and environment (O_2 present or absent), many of the polymers may be expected to exhibit lower radiation resistance than indicated. In particular, PTFE (Teflon) is sensitive to the presence of oxygen. Low dose rate may cause lower radiation resistance of polymeric materials.

Note: Common trade and commercial names of Teflon™-like materials (polymers containing fluorine) include: Algotlon, Duroid, Fluon, Fluorocomp, Gore-Tex, Halon TFE, Hostoflon TF, Kalrez perfluoroelastomer, Kel-F polychlorotrifluoroethylene, Neoflon, Polycomp, Polyflon, and Teflon™.

Basis: LANLs response to TA-55 Type A Investigation and Laboratory Corrective Action Plan, LANL ID No. 00-019. Teflon™ experiences significant degradation of many mechanical properties, including tensile strength, shear strength, elastic modulus, impact strength, and elongation at lower radiation exposure levels than most plastics. Table 6.2-1, extracted from the references below the table shows the

impacts of penetrating gamma radiation exposure on Teflon™ relative to other common plastics.

6.2.2 Plastic Stability

Table 6.2-1 Relative Stability of Plastics

Material	Radiation Dosage for Threshold Damage (rad - gamma)	Radiation Dosage for 25% Damage (rad - gamma)
Polyimide, aromatic	$>10^{10}$	
PEEK	9×10^8	2×10^9
Polystyrene	8×10^7	6×10^9
Phenol formaldehyde (asbestos filler)	3.9×10^8	3.9×10^9
Polyester (mineral filler)	8.7×10^7	3.9×10^9
Polyvinyl Chloride	7×10^7	7×10^8
Polyethylene	1.9×10^7	9.3×10^7
EPDM, EPM	7×10^7	3×10^8
Silicone rubber	6×10^6	1×10^8
Viton A, HFP-VF	9×10^6	5×10^7
Urea formaldehyde (unfilled)	2×10^6	2×10^7
Monochlorotrifluoro-ehthylene (KelF)	8×10^6	8×10^7
Cellulose acetate	2.7×10^7	1.9×10^8
Phenol formaldehyde (unfilled)	$2.7 \times 10^{\mathbf{6}}$	1.1×10^7
Poly methyl methacrylate	7×10^4	8×10^7
Polyester (unfilled)	3.4×10^5	8.7×10^5
Polytetrafluoroethylene (Teflon™)	6×10^5	5×10^6

Basis: Per DOE-HDBK-1132-99, the general rule for elastomers used for sealing is that total radiation levels of 10^7 rads represent the warning point that elastomers may be losing their ability to maintain a seal. At 10^8 rads, virtually all elastomers used for sealing lose their ability to maintain a seal. Typical failures for penetrating exposure occur as a result of

compression set (i.e., the elastomer becomes brittle and loses its ability to spring back). At 10^6 rads, on the other hand, the total damage is relatively minor, and most elastomers maintain their ability to maintain a seal. At 10^7 rads, the ability of an elastomer to maintain a seal becomes totally dependent on the chemical compounding of the elastomer in question. It only takes about two weeks for an elastomer to receive 10^7 rads at a dose rate of 2.88×10^4 rads/hr. Basis is not intended to imply high dose rates are acceptable or recommendable.

7.0 RECOMMENDED AND GOOD PRACTICES

The information provided in this section is recommended based on acceptable industry practices and should be implemented by each user based on the unique application and operating history of the subject systems/equipment.

7.1 Operations Recommendations

7.1.1 Unacceptable Failure

Polymeric seals are not recommended for use in radiological service where failure is unacceptable and either of the following apply:

- Conservative estimates of radiation exposure exceed the damage thresholds.
- Seal replacement cannot be performed before significant degradation might be expected of the polymeric material.

In these instances, metal seals are recommended. Metal seals are also preferable where outgassing or leakage is detrimental, such as in radioactive or toxic gas and high vacuum systems. The LANL Engineering Manual Mechanical chapter provides additional information about seal selection.

An inventory of polymeric seals that potentially will incur a dose large than one half of the damage threshold and that provide a safety barrier will be maintained. A positive method to identify the seal will be provided in close proximity to the seal. This positive identification can be a barcode or other identifying symbol. Information in the inventory of these materials should include:

a. The location of the seal.

b. The type of the seal.

c. The expected time when the damage threshold is reached.

d. Preventive measures to determine the continued safety integrity of the sealing material.

e. Other relevant information.

Alternative materials to Teflon such as polyethylene, EPDM, and EPR, have radiation damage threshold values three to four orders of magnitude higher than that of Teflon. Based on the EPRI studies, these materials would supposedly not reach their radiation damage threshold for 1,000 to 10,000 times as long as Teflon. Qualitatively, PEEK is even more radiation resistant than polyethylene, EPDM, and EPR but by how much is not known. Selection of sealing material must be based on chemical and temperature compatibility in addition to performance in radiation environments.

Basis: LA-UR-00-5918, *An Investigation and Literature Survey of the Performance of Teflon and other Elastomeric Materials in Radiolytic Environments,* Project No. MTL-MS-00-025.

7.2 Maintenance Recommendations

None.

8.0 GUIDANCE

This section provides guidance on how to implement the requirements and recommendations delineated in Sections 6.0 and 7.0 above. The intent is to provide guidance to the criterion user for the development and implementation of his or her program and to prevent each FOD/user from re-inventing the wheel for acceptable program development and implementation.

8.1 Operations Guidance

No implementing guidance available.

8.2 Maintenance Guidance

8.2.1 Damage Threshold Calculations

Conservative estimates should be made of the dose that any polymeric sealing materials will incur during their expected operating lifetime. These conservative estimates should utilize measurements of the source term in the region of application. Mitigating factors such as filters should be taken account of in the estimates. Where neutron or gamma radiation may cause seal failures, radiation surveys can be used to estimate the dose. The conservative estimates of dose along with the intended service lifetime should be compared to the damage thresholds to develop an estimate of the fraction of the threshold that the material would attain in its operating lifetime.

9.0 REQUIRED DOCUMENTATION

Record keeping shall be consistent with the facility's Quality Assurance program.

- Seal inventory. (Section 7.1)
- Periodic Inspections.
- Expected time when damage threshold is resulted. (Section 7.1)
- Record of seal replacement.

Basis Compliance with the requirements of 10 CFR 830.120

9.1 Recommended Documentation

None.

10.0 REFERENCES

The following references, and associated revisions, were used in the development of this document.

10.1 10 CFR 830.120, *Maintenance Management*

10.2 *A Review of Equipment Aging Theory and Technology*, Electric Power Research Institute, NP-1558, Palo Alto, CA, September 1980

10.3 *An Investigation and Literature Survey of the Performance of Teflon and other Elastomeric Materials in Radiolytic Environments*, by L. Dale Sivils and Michael Aire, C-ACT, LA-UR-00-5918, Project No. MTL-MS-00-025

10.4 AP-341-502, *Management Level Determination*

10.5 AP-341-516, *Operability Determination and Functionality Assessment*

10.6 DOE Handbook 1132-99, *Design Considerations*

10.7 DOE Order 433.1A, *Maintenance Management Program for DOE Nuclear Facilities*

10.8 *Effects of Radiation Resistance on Materials and Components*, M. H. Van de Voorde (1970)

10.9 *Effects of Tritium Exposure on UHMW-PE, PTFE, and Vespel (U)*, E.A. Clark, K.L. Shanahan, WSRC-STI-2006-0049 (2006)

10.10 *Irradiation Effects on Polymers*, Chapter 3, "Radiation Resistance of Polymers and Composites" R. L. Clough and K.T. Gillen (1991)

10.11 *Irradiation Effects on Polymers*, Chapter 9, "Polymers in the Nuclear Power Industry" D.C. Phillips and S.C. Burnay (1991)

10.12 *Journal of Nuclear Materials*, "Irradiation Performance Of Polytetrafluoroethylene (Teflon) In A Mixed Fast Neutron And Gamma Radiation Field", O.K. Harling, G.E. Kohse, K.J. Riley J. (2002)

10.13 *Macromolecular Materials and Engineering* , "The Influence of the Irradiation Temperature on the Ratio of Chain Scission to Branching Reactions in Electron Beam Irradiated Polytetrafluoroethylene (PTFE)", U. Lappan, U. Geissler, U. Scheler. (2007)

10.14 *Nucleonics*, "Radiation Effects on Organic Materials", J.G. Carroll, R.O. Bolt (1960)

10.15 P 315, *Conduct of Operations Manual*

10.16 P 342, *LANL Engineering Standards Manual*, Chapter 6

10.17 P 950, *Conduct of Maintenance*

10.18 PD 311, *Requirements System and Hierarchy*, Rev. 1

10.19 *Polymer Degradation and Stability* , "Cross-Linking Of Polytetrafluoroethylene During Room-Temperature Irradiation", D.L. Pugmire, C.J. Wetteland, W.S. Duncan, R.E. Lakis, D.S. Schwartz (2009)

10.20 *Radiation Physics and Chemistry*, "A Review of Radiation Resistance for Plastic and Elastomeric Materials", K. Wundrich (1985)

10.21 *Radiation Resistance on Polymeric Materials*, T. E. Skidmore and H. E. Shook (1995)

10.22 *Type A Accident Investigation of the March 16, 2000 Plutonium-238 Multiple Intake Event at the Plutonium Facility, Los Alamos National Laboratory, New Mexico, dated July 2000*, DOE ES&H Office of Oversight

11.0 APPENDICES

None.