WCAP-8587 "Methodology for Qualifying Westinghouse WRD Supplied NSSS Safety Related Electrical Equipment"

Revision 4

Instruction Sheet

The following instructional information and check list is being furnished to help insert Revision 4 into WCAP-8587 Class 3. Discard the old sheets and insert the new sheets as listed below.

Remove (Front/Back)	Insert (Front/Back)
Cover sheet/--	Cover sheet/--
ii/iii	ii/iii
8-1/8-2	8-1/8-2
Appendix A	Appendix A
--------	Appendix C

Revision 4
January,1981

8102280585

WESTINGHOUSE CLASS 3

WCAP 8587 Rev. 4

Methodology for Qualifying Westinghouse WRD Supplied NSSS Safety Related Electrical Equipment

By:

G. Butterworth

R. B. Miller

January, 1981

Approved: T. F. Hursen

T. F. Hursen
Manager, Nuclear Equipment Engineering

T. M. Anderson

T. M. Anderson
Manager, Nuclear Safety Department

S. Ramchandran

S. Ramchandran
Manager, Electrical Systems Application

Westinghouse Electric Corporation
Power Systems
Box 355
Pittsburgh, PA 15230

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont)

8.0 REFERENCES

Ref. 1. IEEE NPEC SC2 WG 2.6 Synergistic Effects on Environmental Qualification - Draft Environmental Qualification Parameters, 1978.

Ref. 2. Jarecki, S. J., "General Method of Developing Multifrequency Biaxial Test Inputs for Bistables," WCAP-8695 (Non-Proprietary), WCAP-8624 (Proprietary), September 1975.

Ref. 3. Hsieh, T., Barlow, R. T. and Julian, H. V., Environmental Qualification Instrument Transmittor Temperature Transient Analysis WCAP-8936 (Proprietary) WCAP-8937 (Non-Proprietary) February 1977.

Ref. 4. NRC Report - "Short Term Safety Assessment on the Environmental Qualification of Safety Related Electrical Equipment of SEP Operating Reactors," NUREG-0458, May 1978.

Ref. 5. Bordelon, F. M., Murphy, E. T., WCAP-8327, Containment Pressure Analysis Code (COCO) July 1974.

Ref. 6. Letter to Mr. D. B. Vassallo, Chief, Light Water Reactors Project Branch 6, USNRC from Mr. C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated March 17, 1976 (NS-CE-992).

Ref. 7. Letter to Mr. D. V. Vassallo, Chief, Light Water Reactors Project Branch 6, USNRC from Mr. C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated July 10, 1975 (NS-CE-692).

Ref. 8. Letter to Mr. D. V. Vassallo, Chief, Light Water Reactors Project Branch 6, USNRC from Mr. C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated April 7, 1976 (NS-CE-1021).

Ref. 9. Letter to Mr. J. F. Stolz, Chief, Light Water Reactor Project Branch 6, USNRC from Mr. C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated August 27, 1976 (NS-CE-1183).

Ref. 10. T. Hsieh, et. al., WCAP-8936, "Environmental Qualification Instrument Transmitter Temperature Transient Analysis," February 1977.

Ref. 11. Letter to John F. Stolz, Chief, Light Water Reactors Project, Branch 6, USNRC from C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated June 14, 1977 (NS-CE-1453).

APPENDIX A

EQUIPMENT QUALIFICATION DATA PACKAGE

This document contains information, relative to the qualification of the equipment identified below, in accordance with the methodology of WCAP 8587. The Specification section (Section 1) defines the assumed limits for the equipment qualification and constitute interface requirements to the user.

APPROVED: [signature]
for T. M. Anderson, Manager
Nuclear Safety Department

Westinghouse Electric Corporation
Nuclear Energy Systems
P.O. Box 355
Pittsburgh, Pennsylvania 15230

SECTION 1 - SPECIFICATIONS

1.0 PERFORMANCE SPECIFICATIONS

1.1 Electrical Requirements

1.1.1 Voltage:

1.1.2 Frequency:

1.1.3 Load:

1.1.4 Electromagnetic Interference:

1.1.5 Other:

1.2 Installation Requirements:

1.3 Auxiliary Devices:

1.4 Preventative Maintenance Schedule: The details of any preventative maintenance schedule, assumed in establishing the qualified life, will be specified in this section on completion of the Westinghouse Aging Evaluation Program.

1.5 Design Life:

1.6 Operating Cycles (Expected number of cycles during design life, including test):

1.7 Performance Requirements for[b]:

	Parameter	Normal Conditions	Abnormal Conditions	Test Conditions	FLB/SLB	LOCA	Seismic	FLB/SLB	LOCA	Seismic
		Containment		DBE Conditions(a)		Post DBE Conditions(a)				
1.7.1	Time requirement									
1.7.2	Performance requirement									

1.8 Environmental Conditions for Same Function[b]

1.8.1 Temperature (^{o}F)

1.8.2 Pressure (psig)

1.8.3 Humidity (% RH)

1.8.4 Radiation (R)

1.8.5 Chemicals

1.8.6 Vibration

1.8.7 Acceleration (g)

Notes: a: DBE is the Design Basis Event.
b: Margin is not included in the parameters of this section.

1.9 Qualified Life: The demonstrated qualified life will be specified in this section on completion of Subprogram C of the Westinghouse Aging Evaluation Program. (Appendix B to WCAP-8587)

1.10 Remarks: None

SECTION 2 - QUALIFICATION BY TEST

2.0 TEST PLAN

2.1 Equipment Description:

2.2 Number Tested:

2.3 Mounting:

2.4 Connections:

2.5 Aging Simulation Procedure

By a separate component text program as described by Subprogram C of Appendix B to WCAP-8587.

2.6 Service Conditions to be Simulated by Test[1]

		Normal	Abnormal	Containment Test	Seismic	HELB	Post-HELB
2.6.1	Temp. (^{o}F)						
2.6.2	Pressure (psig)						
2.6.3	Humidity (% RH)						
2.6.4	Radiation (R)						
2.6.5	Chemicals						
2.6.6	Vibration						
2.6.7	Acceleration (g)						

2.7 Measured Variables

This section identifies the parameters required to be measured during the test sequence(s).

		Required	Not Required
2.7.1	Category I - Environment		
2.7.1.1	Temperature		
2.7.1.2	Pressure		
2.7.1.3	Moisture		
2.7.1.4	Composition		
2.7.1.5	Seismic Acceleration		
2.7.1.6	Time		
2.7.2	Category II - Input Electrical Characteristics		
2.7.2.1	Voltage		
2.7.2.2	Current		
2.7.2.3	Frequency		
2.7.2.4	Power		
2.7.2.5	Other		
2.7.3	Category III - Fluid Characteristics		
2.7.3.1	Chemical Composition		
2.7.3.2	Flow Rate		
2.7.3.3	Spray		
2.7.3.4	Temperature		
2.7.4	Category IV - Radiological Features		
2.7.4.1	Energy Type		
2.7.4.2	Energy Level		
2.7.4.3	Dose Rate		
2.7.4.4	Integrated Dose		

		Required	Not Required
2.7.5	Category V - Electrical Characteristics		
2.7.5.1	Insulation Resistance		
2.7.5.2	Output Voltage		
2.7.5.3	Output Current		
2.7.5.4	Output Power		
2.7.5.5	Response Time		
2.7.5.6	Frequency Characteristics		
2.7.5.7	Simulated Load		
2.7.6	Category VI - Mechanical Characteristics		
2.7.6.1	Thrust		
2.7.6.2	Torque		
2.7.6.3	Time		
2.7.6.4	Load Profile		
2.7.7	Category VII - Auxiliary Equipment		

2.8 Test Sequence Preferred

This section identifies the preferred test sequences as specified in IEEE-323-74

2.8.1 Inspection of Test Item

2.8.2 Operation (Normal Condition)

2.8.3 Operation (Performance Specifications Extremes, Section 1)

2.8.4 Simulated Aging

2.8.5 Vibration

2.8.6 Operation (Simulated High Energy Line Break Conditions)

2.8.7 Operation (Simulated Post HELB Conditions)

2.8.8 Disassembly and Inspection

2.9 Test Sequence Actual

This section identifies the actual test sequence(s) which, in total, constitutes the overall qualification program for this equipment. The separate subsections indicate the separate test sequences completed on differing, but essentially identical, equipment and/or components. The jus .fication for employing anything other than the preferred sequence is as follows;

Step	Notes
2.9.1 Seismic Test Sequence	
2.8.1	
2.8.2	Seismic (DBE) test sequence
2.8.5	
2.8.8	
2.9.2 Environmental Test Sequence	
2.8.1	
2.8.2	Environmental Type Test Sequence on similar

Step	Notes
2.8.3	piece of equipment as permitted by IEEE-323-74
2.8.8	Section 6.3.2(3).

2.9.3 Aging Test Sequence

2.8.1	
2.8.2	Aging to be addressed by separate te ting as
2.8.4	described in Subprogram C of Appendix B to
2.8.5	WCAP-8587
2.8.8	

2.10 Type Test Data

2.10.1 Objective

The objective of this test program is to demonstrate, employing the recommended practices of Reg. Guide 1.89 (IEEE-323-1974) and Reg. Guide 1.100 (IEEE 344-1975), the capability of the ___ to complete it's/their safety-related function(s) described in EQDP Section 1.7 while exposed to the applicable environments defined in EQDP Section 1.8.

2.10.2 Equipment Tested

2.10.2.1 Normal and Abnormal Environment Testing

2.10.2.2 Seismic Testing

2.10.2.3 Aging Evaluation Program

A representative sample of critical components from the ______ will be included in Subprogram C of the Aging Evaluation Program described in Appendix B to WCAP-8587.

2.10.3 Test Summary

2.10.3.1 Normal and Abnormal Environment Testing

Westinghouse requires that the __ be/are located such that it does/they do not experience a consequent adverse environment when required to operate following a high energy line break either inside or outside containment. Therefore the only environmental testing required is to demonstrate equipment capability under normal and abnormal environmental extremes.

Reference 2 summarizes the results of available radiation testing of organic and inorganic materials and justifies that, for radiation doses less than 10^4 rads, no deterioration in material structural properties is detectable. As a consequence, a radiation simulation is not required on this equipment, since estimated in-service radiation doses will not prejudice the cability of the equipment to perform under design basis event (i.e., seismic event) conditions.

2.10.3.2 Seismic Tests

The single design basis event capable of producing an adverse environment at the equipment location is a seismic event. The seismic testing reported in Reference ___. The generic required response spectrum (Figure 1) contains significant margin with respect to any single plant application referencing this program(1).

2.10.3.3 Aging Evaluation

Subprogram C of the Westinghouse Aging Evaluation Program (Appendix B, WCAP 8587) will incorporate a representative sample of components from the ___. This program is currently in progress and will be Reported in WCAP-8587 Supplement 2, Appendix A, (Non-Proprietary) WCAP-8687, Supplement 2, Appendix A (Proprietary) . The objective of Subprogram C is to demonstrate that during the qualified life there are no in-service aging mechanisms capable of reducing the capability of the __ to perform during or after a seismic event. As a consequence, the seismic testing on the un-aged __ described above, is not prejudiced by any in-service aging mechanism.

2.10.4 Conclusion

The demonstrated qualified life of the __ will be established by Subprogram C of the Westinghouse Aging Evaluation Program. The results of the aging program, together with the seismic and environmental testing described herein, demonstrate the qualification of the ___ employing the practices recommended by Reg. Guide 1.89 and 1.100.

2.11 Section 2 Notes

(1) The generic tests completed by Westinghouse employ parameters designed to envelope a number of plant applications. Margin is a plant specific parameter and will be established by the applicant.

2.12 References

SECTIONS 3 & 4 QUALIFICATION BY EXPERIENCE AND/OR ANALYSIS

Westinghouse does not employ operating experience or analysis in support of the qualification program for ____.

Appendix C

Effects of Gamma Radiation Doses Below 10^4 Rads On the Mechanical Properties of Materials

Introduction

One potential common mode failure mechanism to be considered in the qualification of safety related equipment is gamma radiation. As part of a qualification program, the effect of gamma radiation dose is considered for two purposes: as a component of the High Energy Line Break (HELB) environment and as a potential aging mechanism which could reduce the capability of Class 1E equipment to perform safety related functions under Design Basis Event (DBE) conditions (HELB or seismic). The scope of this report is limited to consideration of the effect of radiation for that substantial portion of equipment outside containment which does not experience an adverse change in external environment as a result of a HELB and for which, therefore, the only gamma radiation concern is as an in-service aging mechanism. This report could be applied to equipment which must perform its function in a HELB if the applicability of the report can be demonstrated, however the information in this report is not adequate to make this determination.

The primary purpose of equipment qualification is to reduce the potential for common-mode failures due to environmental effects during the qualified life. Random failures that inevitably occur in-service are accommodated by the redundancy and diversity of the design of safety systems. Furthermore, in-service maintenance and testing programs are designed to detect such random failures. As a consequence, failures that may be induced in components by gamma radiation alone are considered to be random in nature. The chances of two identical components that perform identical functions failing during the same limited time period in between routine tests is considered insignificant due to:

- the general low failure rate of components used in nuclear equipment,

- the minor differences in component material or geometric tolerances or both, and

- the minor differences in operating environment.

Thus the only gamma radiation concern to be addressed for equipment not subject to an adverse HELB environment is the potential for an aging mechanism resulting in a deterioration in component properties such that, when subject to seismic stress, a common mode failure results. Clearly, when considering such a failure mode, the aging mechanism of concern is not one that affects the electrical properties of components, but one that reduces the mechanical strength and flexibility of components.

Scope

This report summarizes available information concerning the effects of gamma radiation on material mechanical properties and justifies that for a gamma dose of less than 10^4 rads, there are no observable radiation effects which impact material mechanical properties. Of the materials investigated only Teflon TFE is subject to an alteration of mechanical properties for a gamma dose of less than 10^5 rads. Information has been drawn from several sources listed as references on page C-5, they include: various texts concerning radiation effects and damage, and pertinent reports from the Radiation Effects Information Center at the Battelle Memorial Institute in Columbus, Ohio.

Discussion

The primary effects of gamma photons on materials are ionization, material heating (primarily at high dose rates which is of negligible significance here), and some displacement damage caused by high energy photons. Some other types of radiation can have effects similar to those induced by gamma radiation. This allows the use of data obtained from exposure of material to an alternate radiation to provide some limited information concerning the effects of exposure to gamma radiation. For example, the primary consequence of fast neutron bombardment of material is atom displacement. Therefore, if the effect of radiation on a material property is primarily dependent on atom displacement, it can be inferred that for an equivalent dose (rads) of gamma and fast neutron radiation, data obtained from neutron irradiation will provide a conservative estimate of the effect of gamma irradiation in producing displacements. The same type of inference can be drawn for the ionization effect of charged particle (e.g., electron, proton, alpha particle, etc.) irradiation. However, it should be understood that charged particles do not have the penetration capability that gamma or neutron radiations exhibit as a result of extensive interaction between charged particles and atomic charge centers.

Table C-1 summarizes information derived from the listed references which relates to the effect of gamma radiation on material mechanical properties The table presents either the threshold dose (that dose at which an effect on any mechanical property can first be detected) or, if so indicated, the dose which will result in the identified effect. This provides a general indication of the susceptibility of material mechanical properties to gamma radiation.

From an evaluation of the information available on inorganic materials, as summarized in Table C-1, it can be deduced that the mechanical damage threshold for gamma radiation is many orders of magnitude greater than 10^4 rads. For the organic materials listed in Table C-1, a histogram comparing threshold dose level and frequency of material susceptibility is provided in Figure C-1. In instances for which a material threshold dose is not indicated in Table C-1, a threshold value has been assumed which is one order of magnitude lower than the indicated damage dose. Where information is available, referenced documents indicate that the difference between threshold dose and 25% damage dose is in general, approximately a factor of three, thus a factor of ten supplies substantial margin in estimating the threshold dose level. It can be seen in Figure C-1 that any indications of mechanical property, damage thresholds below 10^4 rads would be extremely unusual.

Conclusions

The references listed do not identify the existence of materials whose mechanical properties are deteriorated when exposed to a gamma-radiation dose up to 10^4 rads. As a consequence it can be concluded that common mode failures will not arise in electrical equipment during or after a seismic event as a result of radiation induced degradation up to 10^4 rads.

This conclusion is supported by Nuclear Regulatory Commission (NRC) documentation, available as an attachment to "Guidelines for Evaluating Environmental Qualification of Class 1E Electrical Equipment in Operating Reactors," which provides further justification for the use of 10^4 rads as a threshold for mechanical damage. In comparisons with Table C-1 the NRC information appears to be consistent, thereby raising the confidence level concerning the correctness of both sources.

Recommendations

For Class 1E equipment subject to a lifetime gamma dose of up to 10^4 rads, it is not necessary to address radiation aging for qualification purposes provided that the equipment is not required to perform a safety function in a HELB environment. This conclusion is supported by the text of this report, as no materials reviewed have indicated a degradation of mechanical properties for gamma radiation exposures of up to 10^4 rads. Westinghouse will continue to review information related to the effect of gamma radiation on material mechancial properties. If a material in Westinghouse supplied Class 1E equipment is identified as subject to a significant degradation of mechanical properties as a result of exposure to gamma radiation doses below 10^4 rads, its effect on equipment qualified life will be evaluated on an individual basis and the results reported to the affected customers.

References

1. C. L. Hanks and D. J. Hamman, "The Effect of Radiation on Electrical Insulating Materials," REIC Report No. 46, Radiation Effects Information Center, Battelle Memorial Institute, Columbus, Ohio, June 1969.

2. M. Kangilaski, "The Effects of Neutron Irradiation on St uctural Materials," REIC Report No. 45, Radiation Effects Information Center, Battelle Memorial Institute, Columbus, Ohio, June 1967.

3. C. L. Hanks and D. J. Hamman, "The Effect of Nuclear Radiation on Capacitors," REIC Report No. 44, Radiation Effects Information Center, Battelle Memorial Institute, Columbus, Ohio, December 1966.

4. W. E. Chapin, J. E. Drennan and D. J. Hamman, "The Effect of Nuclear Radiation on Transducers," REIC Report No. 43, Radiation Effects Information Center, Battelle Memorial Institute, Columbus, Ohio, October 1966.

5. J. E. Drennan and D. J. Hamman, "Space Radiation Damage to Electronic Components and Materials," REIC Report No. 39, Radiation Effects Information Center, Battelle Memorial Institute, Columbus, Ohio, January 1966.

6. F. Larin, "Radiation Effects in Semiconductor Devices," John Wiley and Sons, New York, 1968.

7. D. S. Billington and J. H. Crawford, "Radiation Damage in Solids," Princeton University Press, Princeton, New Jersey, 1961.

8. J. W. Corbett, "Electron Radiation Damage in Semiconductors and Metals," Academic Press, New York, 1966.

9. L. W. Ricketts, "Fundamentals of Nuclear Hardening of Electronic Equipment," Wiley-Interscience, New York, 1972.

10. J. F. Kircher and Richard E. Bowman, "Effect of Radiation on Materials and Components," Reinhold Publishing Corp., New York, 1964.

11. R. O. Bolt and J. G. Carroll, "Radiation Effects on Organic Materials," Academic Press, New York, 1963.

12. Irving Kaplan, "Nuclear Physics," Addison-Wesley, 1962.

TABLE C-1

RADIATION INDUCED DEGRADATION
OF MATERIAL MECHANICAL PROPERTIES

MATERIAL	THRESHOLD DOSE FOR MECHANICAL DAMAGE	COMMENTS
Structural Metals	10^{19} n/cm^2 (fast neutron spectrum)	Similar to cold work ($\sim 10^{10}$ rads)
Inorganic Materials	$\sim 10^{17}$ n/cm^2 (fast neutron spectrum)	Borated materials will have lower threshold values for neutron irradiation.
Elastomers		
Natural Rubber	2×10^6 rads(C)	
Polyurethane Rubber	9×10^5 rads(C)	
Styrene-Butadiene Rubber	2×10^6 rads(C)	
Nitrile Rubber	7×10^6 rads(C)	Compression Set is 25% degraded
Neoprene Rubber	7×10^6 rads(C)	
Hypalon	$\sim 10^7$ rads(C)	Variable
Acrylic Rubber	9×10^7 rads(C)	Variable
Silicone Rubber	10^7 rads(C)	$\sim$25% damage
Fluorocarbon Rubber	9×10^7 rads(C)	$\sim$25% Hardness, 80% Elongation
Polysulfate Rubber	10^8 rads(C)	
Butyl Rubber	10^7 rads(C)	$\sim$25% damage

1 Rad (C) is the field of radiation which will produce 100 ergs/gm in carbon.

TABLE C-1 (Continued)

RADIATION INDUCED DEGRADATION
OF MATERIAL MECHANICAL PROPERTIES

MATERIAL	THRESHOLD DOSE FOR MECHANICAL DAMAGE	COMMENTS
Plastic		
Teflon TFE	1.7×10^4 rads(C)	
Kel-F	1.3×10^6 rads(C)	
Polyethylene	$>10^7$ rads(C)	
Polystyrene	10^8 rads	
Mylar	10^6 rads(C)	Conservative
Polyamide (Nylon)	8.6×10^5 rads(C)	
Diallyl Phthalate	10^8 rads(C)	
Polypropylene	10^7 rads(C)	
Polyurethane	7×10^8 rads(C)	
Kynar (400)	10^7 rads(C)	
Acrylics	8.2×10^5 rads	
Amino Resins	10^6 rads	
Aromatic Amide-Imide Resins	10^7 rads	
Cellulose Derivatives	3×10^7 rads	25% damage
Polyester, Glass Filled	8.7×10^8 rads	
Phenolics	3×10^8 rads(C)	25% damage
Silcones	10^8 rads(C)	
Polycarbonate Resins	5×10^7 rads	25% damage to elongation

TABLE C-1 (Continued)

RADIATION INDUCED DEGRADATION
OF MATERIAL MECHANICAL PROPERTIES

MATERIAL	THRESHOLD DOSE FOR MECHANICAL DAMAGE	COMMENTS
Plastic (Cont.)		
Polyesters	$\sim 10^5$ - 10^6 rads	
Styrene Polymers	4×10^7 rads	
Styrene Copolymers	4×10^7 rads	25% damage
Vinyl Polymers	1.4×10^6 - 8.8×10^7 rads	
Vinyl Copolymers	1.4×10^6 - 8.8×10^7 rads	
Encapsulating Compounds		
RTV 501	2×10^6 rads	
Sylgard 182	2×10^6 rads	
Sylgard 1383	2×10^6 rads	
Polyurethane Foam	2×10^6 rads	
Epoxies	10^9 rads(C)	

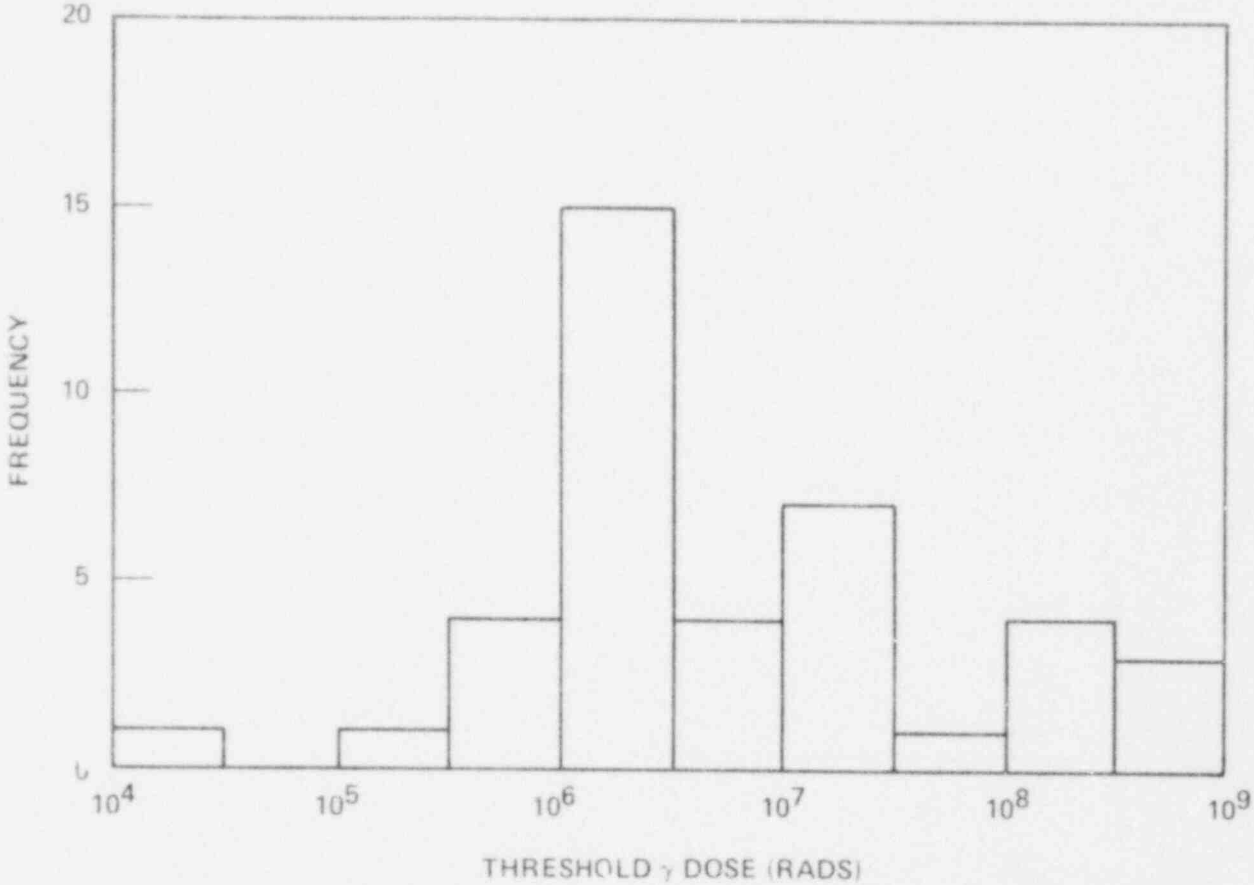

Figure C-1 Histogram of Threshold γ-Dose for Mechanical Damage to Elastomers, Plastics and Encapsulating Compounds