Generic Qualification of Rotary Hand Switches

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EPRI PERSPECTIVE

PROJECT DESCRIPTION

This project under RP1707-8 is part of the EPRI electrical equipment qualification research program (RP1707), which provides technical assistance to utilities in meeting qualification standards and regulations in a manner consistent with the state of the art and at minimum cost. Another project in this program (RP1707-2) has established an Equipment Qualification Data Bank, which disseminates information useful in demonstrating that safety-related electrical equipment in plant areas with a "harsh" environment can function during and after the high temperatures, pressures, and radiation produced by accidents such as a loss of coolant or a high-energy line break. The project reported here, on the other hand, is one of several projects that address qualification of equipment in "mild"-environment plant areas such as the control room. Even during accidents, equipment in these areas does not experience significant increases in environmental parameters and can be qualified by demonstrating that (1) normal or abnormal environments up to the time of a design-basis earthquake are no greater than those for which the equipment was designed and therefore the environments do not produce common-cause failures in redundant safety-related systems and (2) the equipment can function during and after a design-basis earthquake. This study addresses rotary hand switches, a specific type of equipment commonly installed in mild-environment plant areas.

PROJECT OBJECTIVE

The objective is to provide utilities with generic information that can be referenced to support or to demonstrate qualification of safety-related rotary hand switches for operation in mild environments. Seismic qualification of switches falls outside the scope of this study but is included in the scope of RP1707-4, a related current testing program that is examining the correlation between operational aging and seismic performance of a wide range of electrical equipment.

PROJECT RESULTS

This report is a compilation of information on three specific models of switches that have been widely tested and installed in nuclear plants. The information consists of test results, plant experience, materials, environmental stresses, potential failure modes, and surveillance and maintenance procedures. As an example, a fourth specific model of switch is considered in order to demonstrate how the generic data on the three baseline switches can be used to support qualification of other mild-environment switches that are similar with respect to design, environmental stresses, and potential failure mechanisms. This report would be useful for qualification engineers at utilities or engineering firms.

George Sliter, Project Manager
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ABSTRACT

This report is a compilation of generic information that can be referenced to support or demonstrate qualification of safety-related rotary hand switches for operation in "mild" nuclear-plant environments such as that in the control room. Information on three specific models of switches is given including prior test results, plant experience, materials, environmental stresses, potential failure modes, and surveillance/maintenance procedures. As an example, a fourth specific model of switch is addressed to demonstrate how this compilation of generic data can be used to support qualification of other switches on the basis of similarity.

CONTENTS

ILLUSTRATIONS

TABLES

- An example of similarity analysis is provided to demonstrate use of this report for switch acceptance. The design, materials of construction, stresses and failure mechanisms of the Westinghouse PB switch were analyzed with respect to the three "baseline switches".

- An application guide is presented in a general manner to allow the purchaser/user leeway in their specific use of the project results for other rotary hand switches.

Benefits to be derived from this project are:

- Elimination of age testing for qualification of replacement spare parts or switch subassemblies.

- A variety of spare switches in stores inventory may be interchanged within the mild environment.

- Switches installed in operating nuclear plants can be shown to be qualified with support from the procedures and data in this report.

- Additional switch suppliers may become available since qualification of presently available and new generation commercial grade switches can be accomplished by analysis without additional age testing.

In summary, this report, with a documented purchase specification, certificate of compliance, and on-going surveillance and maintenance program will enable the user to demonstrate acceptable application of rotary type hand switches in the mild environment.

SUMMARY

Commercial grade Class 1E equipment must be qualified for service in a nuclear plant mild environment, i.e. an environment expected as a result of normal operating conditions and expected extremes (abnormal) in operating conditions. The objective of this project is to provide the industry with generic information including existing test data and device analysis to support environmental qualification, excluding seismic, of rotary hand switches for nuclear plant mild environment application. Generic information includes analysis of plant experience, testing results, standards, materials, environmental stresses, failure modes, surveillance and maintenance. A summary of the work scope tasks follows:

- Investigate switch materials for aging mechanisms.
- Investigate switch design documents for generic similarities.
- Investigate operational cycling stresses of switches.
- Investigate environmental aging stresses of switches.
- Investigate switch failure mechanisms caused by stresses.
- Review switch qualification and vendor testing data.
- Review operating history of switches in nuclear plants.
- Define switch purchase specification and certificate of compliance content.
- Investigate the surveillance and preventive maintenance necessary to maintain switch qualification.

Three specific switches evaluated in this subgroup of Class 1E devices were the General Electric SBM and CR2940, and Leeds and Northrup 8248-10. These "baseline switches" are acceptable for Class 1E electrical service by virtue of previous testing. Other switches

that are similar and fit in this subgroup with respect to design, materials of construction, stresses and failure mechanisms are also identified in the report. One of these other switches, the Westinghouse PB switch, is evaluated for operability in mild environments by comparison of switch function and materials of construction to the baseline switches. It is expected that additional rotary hand switches, not specifically addressed in this report, will also fall within this grouping by virtue of their similarity and design margin.

Specific project results supporting the acceptability of these rotary hand switches are:

- Test data and operating experience analyses related to switch qualification did not identify any common mode failures. Stresses analyzed were contact thermal stress, mechanical stress, vibration stress, radiation stress, thermal aging stress, cycling stress and stress cracking of materials. Potential failure modes such as failure to make and break, change or hold position, and welded contacts were identified. Potential failure mechanisms such as cracking, contact pitting and wear, and fatigue are also covered.

- Operational and environmental service limits which are acceptable for application of these generically qualified switches are provided for the subgroup. The materials, design, and operational requirements provide the conservative limits listed below:
  --Maximum Operational Temperature: 100°C (212°F).
  --Minimum Radiation Threshold: 10^5 Rads Total Integrated Gamma Dose
  --Testing (Arrhenius Method): 40 years.
  --Operational Cycles: >50,000, low inductive loading.
  >30,000, mid range inductive loading.

- Surveillance and maintenance program guidelines to demonstrate on-going hand switch use in conjunction with the vendor certificate of compliance are developed and presented. For example, chemical action between polycarbonate switch materials and hydrocarbon cleaning solutions can lead to environmental stress cracking or crazing. Therefore hydrocarbon cleaning agents should not be used. Other maintenance and surveillance such as operational test cycling, contact inspection and maintenance or replacement, and potential monitoring techniques such as high pot testing and inspection for crazing are discussed.

- A sample guideline for the preparation of a purchase specification for a mild environment Class 1E rotary hand switch is given.

1.0 INTRODUCTION

1.1 Background

Qualification of Class 1E devices for nuclear plant use is often performed by IEEE Standard 323-1974 type testing, using accelerated aging techniques, to simulate the degradation effects to end of life under the anticipated normal and accident environments. Alternative methods of qualification consist of a combination of analysis, operating history, and testing.

A review of NSSS and vendor data indicates that industry efforts, in some cases, have gone to extremes to meet IEEE Standard 323-1974 requirements. For example, the General Electric Type SBM rotary hand switch has been environmentally qualified a number of times (See Appendix B) for specific plants, and is undergoing qualification testing aging for other users even though the switch has been used for over 20 years as a reliable and low maintenance device. This duplicated effort results in needless expenditure of time and capital.

Draft USNRC Regulatory Guide 1.89 endorses the sequential testing and analysis procedures of IEEE Standard 323-1974 subject to some exceptions. Namely, position statement C.5.a of Regulatory Guide 1.89, stated below, specifically exempts items located in mild environments from the requirements for qualification age testing.

"Section 6.3, "Type Test Procedures", of IEEE Standard 323-1974 should be supplemented with the following:

a. Equipment items identified in items (2) and (3) of Regulatory Position C.4.d are not required to be qualified by test if they are in a mild environment, i.e., an environment that would at no time be more severe than the environment that would occur during normal plant operation or during anticipated operational occurrences. Design or purchase specifications that contain a description of the functional requirements and the specific environmental conditions during normal and abnormal conditions and that are supported by a <u>certificate of compliance based on test data and analysis</u> will generally be acceptable. A well-supported surveillance program in conjunction with a good preventive maintenance program should be provided to ensure that such equipment will function for its design life."

1.2 Objective

The objective of this project is to provide available industry test data and analysis in support of the certificate of compliance to demonstrate that a subgroup of commercial grade Class 1E devices, rotary hand switches, applied in mild environments is environmentally qualified, excluding seismic. Seismic qualification can usually be demonstrated by generic seismic test data provided by suppliers.

1.3 Project Scope

This project reviews and analyzes specific models of rotary hand switches in the subgroup to demonstrate qualification of similar switches for use in plant mild environments. Switches such as snap acting pressure switches and rocker switches are not addressed. The factors studied are:

1. Design Detail and Materials of Construction
2. Test Data
3. Range of Environmental Stress Factors
4. Operating History
5. Surveillance and Maintenance Programs

A goal of this study is to provide assurance of Class 1E device reliable operation in the plant. A certificate of compliance to the purchase specification requirements will be considered as reference qualification documentation when combined with the generic data presented herein. The certificate of compliance contains an auditable trail to reference testing data utilized for qualifying a similar device by serial number, date code or lot number to an equal or more severe stress level than that in the purchase specification. A manufacturer certifies that a Class 1E device has been designed to perform its design function within the specified environmental and operating conditions.

The following report sections develop a methodology which utilizes existing data for the subject devices and considers existing industry test data, analysis, and operating experience to demonstrate that a class of switches is qualified without age testing for use in mild environments. The study will further identify the ongoing surveillance and maintenance programs required to maintain mild environment device qualification.

1.4 Analysis Approach

The project approach will identify the major environmental stresses to which commercial grade Class 1E switches are subjected during operation in mild environments. These stresses and possible resulting degradation or failure mechanisms will be identified and compared to device operating history. From this analysis of stresses and historical data, effects on switch lifetime will be analyzed and recommendations will be presented for purchase specifications. The suggested purchase specification will include criteria by the purchaser for analysis and testing to be provided by the vendor to enable issuance of a certificate of compliance for environmental qualification. Surveillance and maintenance suggestions to ensure continuing qualification will also be presented.

Four specific switches considered in this subgroup of Class 1E devices are the General Electric SBM and CR2940, Leeds and Northrup 8248-10 and Westinghouse PB models. Qualification by similarity analysis of the Westinghouse PB switch is given as an example. Test data is evaluated for the three baseline switches. The switch components and materials of construction of the above four switches are given in Table 6-1 while the switch assembly details and specifications are given in Appendix A.

The items of study are:

1. Design and materials specifications for the representative devices to determine common characteristics and materials.

2. Previous industry qualification test data and vendor test data to determine any degradation induced by the applied stress factors during testing.

3. Stress factors and mechanisms which may lead to degradation.

4. In-service operating history to serve as a check of the conclusions derived from analysis and testing.

5. Surveillance and maintenance programs which flag signs of incipient failures and provide for ongoing qualification.

6. When operational cycling is a significant stress in switch application, a discussion of methods to prevent contact pitting and protect contacts is presented.

2.0 GENERIC FEATURES OF ROTARY HAND SWITCHES

Four rotary type hand switches with common physical characteristics and functional specifications are examined. These switches are the General Electric SBM switch, the General Electric CR2940 switch, the Leeds and Northrup 8248-10 switch, and the Westinghouse PB1 and PB2 series switch. These switches are utilized extensively within PWR and BWR plants for Class 1E service on safety-related systems. The safety systems which use these switches are essential to reactor emergency shutdown, containment isolation, reactor core cooling, containment and reactor heat removal, or essential to preventing a release of radioactive material to the atmosphere. The subgroup of switches has similar operational requirements and materials selection. The switches are designed for rugged service with large handles and strong moving parts. The switches appear on operating panels for use such as reactor mode selection, remote shutdown selection and power switchgear operation. Applications range from 125 VDC switching of inductive relays and solenoids to 50 volts at 20 MA for thermocouple control loop selection.

Summaries of switch operating experience and tests conducted on the General Electric SBM switch are given in Section 4.0 and Appendix B. Test results for the qualification of the Leeds and Northrup 8248-10 and General Electric CR2940 switches are given in references 7.1.4 and 7.1.10. Readily available industry test data that demonstrates qualification is referenced.

2.1 Materials and Construction

The switches being examined have the following common physical characteristics (Refer to Appendix A for device description and sketches).

a. Fixed and moving contacts of precious metal or precious metal alloy composition. One or more sets of contacts for each device. As many as eight contacts per wiper block with stacking of wiper blocks limited by cam torque on the handle.

b. Plastic or ceramic insulation material to support the fixed contacts and provide insulation between multiple sets of contacts.

c. Metallic springs to operate moving contacts or restore them to their original position following operation.

d. Plastic insulating handles for operation.

e. Metallic shafts and plastic cams molded or cut to provide specific contact action.

f. Metallic escutcheon plates with application-specific engraving to denote switch status.

g. Metallic screws, nuts, washers and other hardware for assembly of the switch and termination of wiring to the switch. Solder connections are not used.

2.2 <u>Functional Requirements</u>

The switches being examined have the following common functional requirements (Refer to Appendix A):

a. Maximum allowable applied voltage: AC or DC.

b. Contact current carrying capability for continuous currents: AC or DC.

c. Contact make and break currents: Inductive or resistive.

d. Quantity and arrangement of contacts specifying which contacts are open/closed for the various allowable switch positions.

e. Shaft position and escutcheon engravings.

f. Operating handle shape and size.

g. Capability (number of operating cycles).

h. Service conditions: Temperature, pressure, relative humidity, radiation, vibration.

3.0 STRESS ANALYSIS OF SWITCHES

Device materials for the four switches being analyzed are listed in Table 6-1. Thermal aging susceptibility of the switch parts is low enough to allow at least a 40 year useful life in a mild environment. Contact pitting and operational cycling may limit useful life when a mid range inductive load of 10 amps AC or 400 Milliamps DC is switched 3 to 4 times per day. The contact design life can be extended by good maintenance to renew surfaces and replace worn contacts.

Stresses that could lead to switch degradation or failure are analyzed in the following subsections.

3.1 Contact Thermal Stress

Thermal stress on contact support materials from electrical current self heating contributes to limitation of the switch useful lifetime. Reference 7.2.13 discusses the role of contact resistance in causing internal heating. When current passes between two metallic components, most of the energy dissipated as the charge flows through the contact resistance appears as heat generated in the immediate vicinity of the switch contacts. A constant current will produce a steady condition in which the region of contact flow will be hotter than the surrounding bulk metal. The temperature varies with potential drop across the contact resistance of a silver alloy contact. Maintenance to clean and file contact surfaces will reduce the contact resistance.

Contact current losses generate switch self heating which affects the internal parts susceptible to thermal age related degradation. A polycarbonate cam follower, with mounted switch contacts must transfer contact resistance heating. Materials selected for contact support have both high dielectric strength and thermal activation energy.

Effects of this real time thermal aging are normally not calculated, but can be determined by vendor testing. The significance of internal heating and design thermal margins have been shown through testing of the SBM switch, (reference 7.1.3). This test, at a maximum rated 20 ampere continuous load resulted in a cam follower temperature of 49^{o}C (120^{o}F). The ambient test condition was 27^{o}C (81^{o}F) with a temperature rise of 22^{o}C (39^{o}F). The temperature rise was 38^{o}C (69^{o}F) less than the vendor stated allowable rise of 60^{o}C (108^{o}F) due to cam follower material (Lexan) limitations. Other testing of the switch has been performed at temperatures up to 115^{o}C (239^{o}F) with no degradation or failures experienced. For mild environment application, even with maximum current flow, the testing indicates an ample thermal margin for temperature rating of the weak link Lexan cam follower both for temperature rise and maximum operating temperature. Selection of insulation materials such as Lexan and Delrin are favored by manufacturers for thermal considerations. These are further discussed in the subsection on thermal aging stress.

3.2 Mechanical Stress

The requirements for a contact are simply that it should be a good conductor when closed and a good insulator when open. Major problems can occur due to contact film, which causes appreciable voltage drop. The relations which describe this contact resistance, (reference 7.2.11), are based on the fact that contact surfaces are microscopically rough and touch at the high spots. As a result, the force and compressive properties at the metal's surface, both metal and film, determine the size of the conducting spot. This size and the resistivity of the metal and film determine its resistance. Commercial grade switches with precious metal or precious metal alloy composition contacts permit relatively weak contact forces to maintain low contact resistance. When the contacts close, contact wipe provides a means for removal of some corrosion products.

Switch mechanical stress occurs from contact pressure which may result from the surfaces of two rigid bodies pressing against one another. Since they are rigid, however, they can only be maintained in contact by means of tension on at least one contact. For the SBM switch this is provided by the cam follower with the movable contacts attached. Without this elastic support, the slightest movement, such as shrinkage due to temperature change and shock could result in an open contact. Therefore, the means by which such elastic forces are applied and maintained is considered in design.

The commercial grade rotary switches being analyzed have been used in a variety of applications, both in power plants and other industries without experiencing significant failures. Review of reported operating problems of switches in extensive industrial application does not indicate a significant failure mechanism due to mechanical design or material fatigue. Therefore, no attempt has been made to postulate failure mechanisms which have not been previously identified.

3.3 Vibration Stress

Normal switch vibration is a potential stress factor. A review of reported plant operating experience, Section 4.0, has not indicated any failure modes that could be attributed to vibration coupling between structures and switch locations such as large relay racks, vertical boards, and operator benchboards. Therefore, vibration is not considered a significant stress mechanism leading to switch failures.

3.4 Radiation Stress

Typical mild environment 40 year total integrated dose for a control room is less than 10^3 Rad gamma. Other mild environment areas are slightly higher. Reference 7.2.3 gives minimum radiation thresholds for organic materials. These thresholds for switch materials are given in Table 6-1. The switch materials threshold is 10^5 Rad gamma or greater.

Case 2 of Appendix B documents radiation testing of the SBM switch performed in a radiation chamber loaded with a source of 80,000 curies of Co-60. Exposure was for a 25 hour duration with an estimated dose of 4×10^5 Rads. The switch was subsequently cycled for continuity measurements, seismically tested, and tested for simulated post accident conditions at $66^{o}C$ ($150^{o}F$) and 95% RH. No failures were observed.

3.5 Thermal Aging Stress

Time - temperature artificial age testing is accelerated degradation of materials properties resulting from exposure to other than normal service temperatures. Exposure times at both normal and elevated testing temperatures are related by the Arrhenius relationship.

$$t_1 = t_2 \exp [Ea/k_B \ (1/T_1 - 1/T_2)]$$

where

t_1 = duration of artificial aging (hours)

t_2 = duration of normal service conditions (useful life) (hours)

Ea = activation energy (eV)

k_B = Boltzmann's constant, 8.617×10^{-5} eV/^{o}K

T_1 = artificial aging temperature, ^{o}K

T_2 = normal service temperature, ^{o}K

The SBM switch has undergone accelerated aging tests using Arrhenius methods in a number of cases, (Appendix B). The switch has been artifically aged to a qualified life up to 40 years at maximum temperatures of $115^{o}C$ ($239^{o}F$) during these tests. The SBM Delrin cam with the lowest activation energy of 0.73 ev is the critical part most susceptible to thermal aging degradation.

The GE CR2940, L&N 8248 and Westinghouse PB switches contain cams, contact blocks, seals, and positioner made of materials such as Noryl, Phenolic, Acetal and Lexan with activation energies of 0.84 or greater.

Figure 3-1 shows an Arrhenius plot, for 40 year life, for the SBM and PB switches with a limiting activation energy of 0.73 ev and the other switches with limiting activation energy of 0.84 ev. The baseline temperature is $25^{o}C$ ($77^{o}F$) for 40 years.

The results from the Arrhenius plot indicate that the GE CR2940, L&N 8248, and Westinghouse PB switches are less susceptible to thermal aging then the SBM switch which has been qualified for a 40 year life. The conclusion is that switches with any of the materials identified here do not have age sensitive mechanisms associated with useful lives less than 40 years.

3.6 Cycling Stress

Operational cycling load will generally be the limiting life factor for switches. A method of predicting switch lifetimes considering stress factors due to device service conditions, cycling rate, and electrical loading is provided by the Military Standardization Handbook for Reliability Prediction of Electronic Equipment, MIL-HDBK-217C, (reference 7.2.8).

For rotary type switches, MIL-HDBK-217C presents a failure rate model given by the expression:

$$\lambda_p = \lambda_b \; (\Pi_E \cdot \Pi_{CYC} \cdot \Pi_L) \quad \text{failures}/10^6 \text{ hours}$$

Where:

Π_E is the environmental factor based on service conditions and is equal to 1.0 for minimum environmental stress with optimum operation and maintenance.

Π_{CYC} is the cycling rate factor and is equal to 1.0 for a switching cycle rate of less than or equal to 1 cycle/hr and is operational dependent.

Π_L is the switch contact stress factor dependent on resistive or inductive load. For a reasonable resistive load current of 30% of rated, Π_L is 1.15 and is engineering application dependent.

$\lambda_b = \lambda_{bE} + n\lambda_{bG}$ represents the base failure rate model for rotary switch medium power wafers. n is the number of active contacts and λ_{bE} and λ_{bG} are conservatively given as 0.1 and 0.6 for non MIL-SPEC devices. For the ten stage SB switch $\lambda_b = 0.1 + 20\ (0.06) = 1.3$.

Substituting into the failure rate model equation:

$$\lambda_p = 1.5 \text{ failures}/10^6 \text{ hours}$$

The assumption of 1 switch cycle per hour or 10^6 cycles/10^6 hours yields approximately 700,000 cycles/failure

Similar analysis of the CR2940 at 30% stress factor with resistive load and at 70% stress factor with inductive load yields the following results:

Switch	30% Stress Resistive	70% Stress Inductive	Manufacturer's Cycle Rating
GE SBM	7×10^5 Cycles/ Failure	3.6×10^4 Cycles/ Failure	5×10^5
GE CR2940	1.5×10^6 Cycles/ Failure	7×10^4 Cycles/ Failure	1×10^5

High electrical stress has been observed during vendor acceptance testing. Appendix B, (case 1) documents that the SBM switch experienced contact failure at approximately 30,000 cycles under high current inductive loading of 2 amperes at 125 VDC and failure at two cycles when subjected to 4 amperes inductive loading at 125 VDC.

This analysis, based on typical mild environment installations and electrical stress application suggests that these switches will operate for a number of cycles comparable to the manufacturer's mechanical cycle rating and are therefore appropriately rated, or possible conservatively rated with respect to cycling at expected or typical low electrical loading and stress. The switches are inappropriately rated for a high direct current inductive loading stress, however application of these switches with this high direct current inductive loading service is rare.

Cycling stresses can be reduced and one method of extending contact life when applying the SBM switch should be noted. In the BWR-6 solid state system, a high contact voltage is maintained across the open switch contacts by a capacitor discharge circuit. When the switch is closed, the capacitor discharge burns through oxide build up. Continuous contact make current for the solid state logic is maintained at 30MA to reduce catalytic oxidation which can occur at 5MA and below. Opening the normal make logic current of 30MA does not result in the metal depletion that results from arcing. The switch design life and consequent reliability is improved by this engineering modification to avoid contact damaging inductive load kick back. Diode transient suppressors or MOV's, (metal oxide varistors), to absorb high energy voltage transients will extend the useful life of all relay and switch contacts. Figure 3-2 shows a typical operating diagram for protective circuits, (reference 7.2.7).

3.7 Stress Cracking

Cam follower material such as Lexan, a polycarbonate, is not resistant to acids, alkalies, aromatic and chlorinated hydrocarbons. Chemical action between polycarbonates and hydrocarbons, such as used in some cleaning solutions, can result in fine cracks that propagate in a network on or under the surface through a layer of material. The end effect is what the plastics industry terms environmental stress cracking (ESC), that is, susceptibility of a thermoplastic to crack or craze under the influence of chemical treatment and/or mechanical stress. Potential stress resulting in crazing or cracking of polycarbonate materials is analyzed in Section 5.0.

3.8 Stress Analysis Summary

Table 3-1 summarizes potential rotary hand switch stresses and failure mechanisms. These stresses on switches in mild environments are low and as shown are well within the design margins.

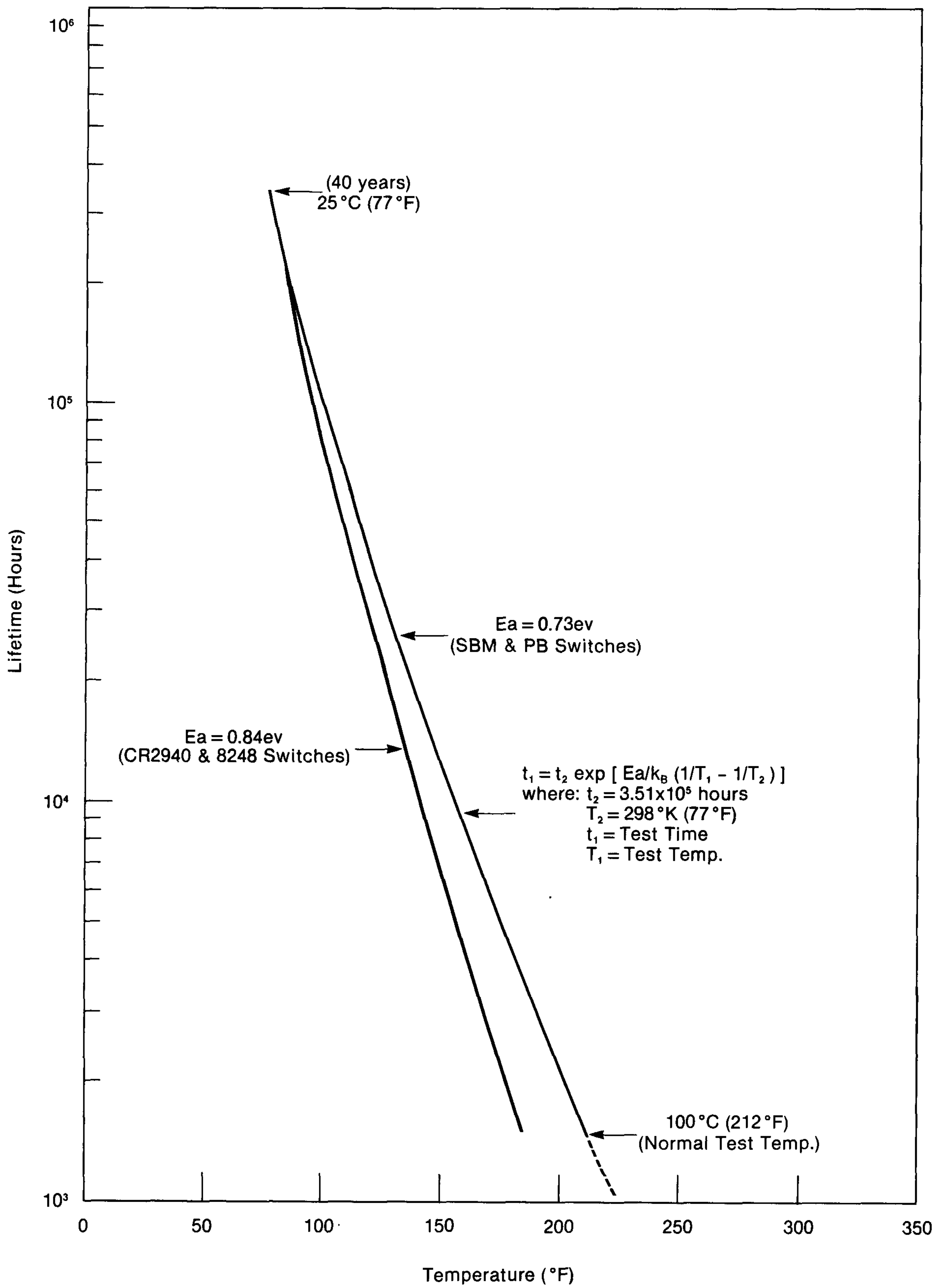

Figure 3-1. Arrhenius Plot - Switches

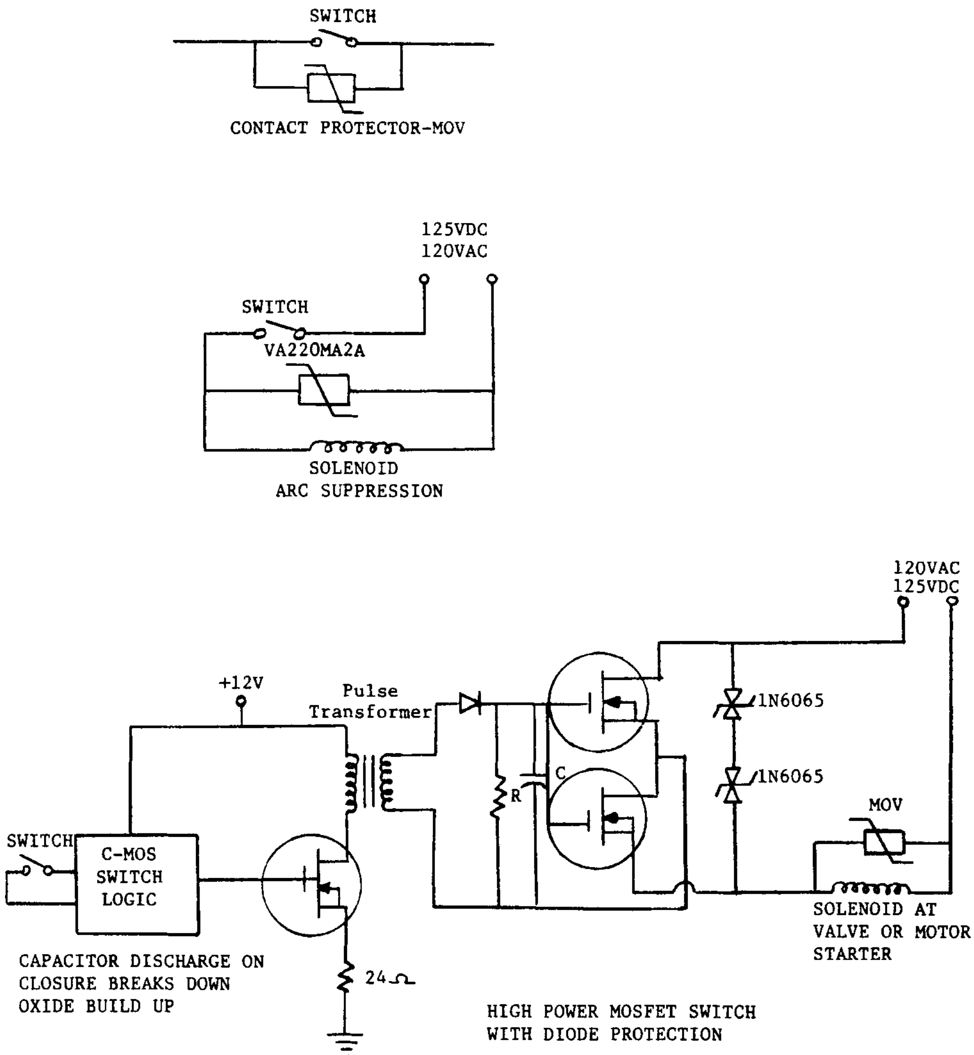

Figure 3-2. Typical Contact Protective Circuits

Table 3-1

ROTARY HAND SWITCH STRESSES AND FAILURE MECHANISMS

Failure Mode	Failure Mechanism	Stress Factor
1. Failure to make (close)	Cracked cam follower worn contacts	Mechanical stress Chemical treatment Operational cycling Thermal aging Thermal crazing Vibration - Shock
2. Failure to break (open)	Cracked cam follower	Mechanical stress Chemical treatment Operational cycling Thermal aging Thermal crazing Vibration - Shock
3. Failure to change switch position (jam)	Cracked cam follower	Mechanical stress Chemical treatment Operational cycling Thermal aging Thermal crazing Vibration - Shock
4. Welded contacts	pitting wear metal fatigue due to heat	Thermal stress Corrosion Electrical Current overloads (Inductive switching transients) Electrical transients (Voltage Arcing)
5. Will not hold position (no detent)	screw that supports the roller arm falls out- spring failure	Vibration Corrosion Defective Materials

4.0 OPERATING EXPERIENCE

The preceding section analyzed switch stresses and potential failure mechanisms and failure modes. Nuclear Plant Licensee Event Reports (LERs) were reviewed to determine any reportable events associated with rotary hand switch problems. Reported events are summarized below.

LER AO 76-4W, March 1975, Browns Ferry, FitzPatrick, Peach Bottom, and Brunswick.

In March 1976, GE issued a service information letter explaining recent problems with the GE SBM control Switch. These switches were widely applied at fossil, BWR and PWR plants. Reported failures, however were limited to fossil plant application. The problems were diagnosed as fracture of the Lexan cam followers attributed to exposure of some to hydrocarbons. This cam follower degradation could lead to failure of the switch to open, to close or jamming of the switch mechanism.

Cam followers in question had been exposed to hydrocarbons during the manufacturing period from July 1972 through May 1975. A records search included application of these switches as follows; 9 at FitzPatrick, 3 at Peach Bottom 2, 3 at Peach Bottom 3, and 1 at Brunswick 2.

Recommended actions were:

1. Replace any SBM Switches in Class 1E Application that were identified as in the affected series.

2. For the affected switches, with application other than class 1E, the cam followers should be inspected for cracks with an auxiliary light source through openings near the terminals of each switch deck. Disassembly was not recommended.

In April 1976, during pre-op testing after a fire at Browns Ferry, an RCIC pump discharge valve would not operate. Investigation revealed failure of a GE SBM switch. The switch was replaced and other SBM switches inspected. A large number of cam followers with a crazed appearance were noted A total of 420 switches were replaced at the 3 plants of which 237 contained crazed cam followers, 12 had cracked cam followers, 33 had been subjected to cable fire residue, and 138 had been manufactured during the period in question. Procedures were revised to prohibit the use of hydrocarbons in the form of cleansers and lubricants on SBM Switches. The cracked appearance of the cam followers was also attributed to excessive force being applied to fit pivot pins through the cam followers. GE revised the assembly process to reduce the amount of force.

LER 75-37, March 1975, Hatch 1.

While investigating a problem with an alarm circuit, an auto start signal to the standby Gas Treatment System Train A was initiated and the system failed to start automatically. The A Train was declared inoperable. An investigation determined that a GE type SBM switch contact failed to close when the switch was placed in auto due to broken contact. The contact was replaced with a new one of the same type.

LER 76-2, Feb. 1976, Ft. Calhoun.

On completion of a test, a sequencer for a HPSI pump failed to return to Auto Standby. The cause was reported as a dirty contact on a GE type SBM control switch.

LER 75-12, April 1975, Three Mile Island 1.

During safety injection testing, a RB Emergency Cooling River Water pump failed to start on an automatic ESF signal. The reported cause was an intermittent contact on a GE SB-10 control switch. The switch was replaced.

Miscellaneous LERs, 1975-1982, PWRs and BWRs.

Approximately twenty additional LERs (reference 7.3) reporting switch problems were reviewed. The majority of these events occurred because of tarnished, dirty or loose contacts and problems with manufacturing tolerances and friction. Other problems noted were loose wires and oxide film buildup. None of these events indicated a common mode of failure for the rotary hand switches since only specific lots of switches and maintenance activities were responsible for the problems.

5.0 SURVEILLANCE AND MAINTENANCE

5.1 Background

The operating history of rotary hand switches such as the four switches analyzed shows them to be a low maintenance device even in applications other than nuclear plant mild environments. Reference 7.5.2 states that over 2.5 Million SBM switches were sold between 1970 and 1975. Few failures have been noted as summarized in the operating experience of Section 4.0.

Switch applications have been in the range of 150 ma at 125 VDC inductive load. Operation at these levels provides for ample margin from switch maximum ratings. Stress analysis in section 3.0 demonstrated that the switch design provides ample margin from degradation stresses due to mechanical cycling, electrical stress, temperature rise and average operating device temperature.

5.2 Normal Plant Surveillance/Maintenance

Operational surveillance testing of hand switches normally consists of cycling checks to verify operability by observing system status lights, alarms, or other indications of switching action. The switches, depending on which plant system they are in, are also operated during technical specification required system surveillance testing such as diesel generator testing, load shed and blackout testing, and verification of remote shutdown panel capability. During these plant specific operability checks, malfunctions or impending failures can be detected and actions taken for maintenance or repair. Replacement of the total switch or contact assembly has been the normal corrective action.

Good plant operating preventive maintenance procedures will assure logging of switch problems and identification of loose mountings or binding shaft alignment. Once properly installed and operational the switches are a low maintenance item.

Vendor recommendations for inspection, maintenance, and repair for one switch, the General Electric Type SBM, are given in reference 7.4.1. These are summarized as follows:

> At regular intervals, switches should be inspected for burning of contacts, for broken shunts on the moving contacts and for contact wipe. If the contacts are slightly pitted, or coated with sulphide, they should be scraped gently with a sharp knife or dressed with a fine file. If the shunts are broken or the movable contacts badly burned or pitted, the entire contact assembly should be replaced. Damage to a fixed contact requires replacement of the complete assembly of fixed contacts and support. Additional recommendations are given for switch dis-assembly, replacement of parts, and switch assembly. Appendix A shows recommended spare parts for the SBM switch.

However, switch contact burning or pitting may indicate problems with loading which justifies a check of circuit electrical loading. In addition, installation of new contacts rather than dressing or filing is advisable and normally performed at nuclear plants. Inspection of contacts should be performed with care, since the making and breaking switch action and transfer of material could tend to wipe and mask any initial darkening, burning or pitting.

5.3 Special Maintenance Considerations

As previously described, the SBM cam follower is Lexan, a polycarbonate, and is not resistant to hydrocarbons. Chemical action between polycarbonate and hydrocarbon cleaning solutions used in cleaning dust and contaminants from the switch can lead to environmental stress cracking.

Reference 7.5.1 documents a case which demonstrated potential problems with the SBM switch during pre-operational testing at a fossil plant. The Lexan cam follower cracked when the shaft was rotated. The failure mode was identified by the vendor as a fractured cam follower attributed to chemical action between the Lexan and a mild hydrocarbon resulting in environmental stress cracking. The hydrocarbon cleaning agent had been applied at one of the manufacturing facilities. Investigation revealed that this was an isolated case at only one manufacturing plant. Reference 7.5.2 states that the manufacturer's instruction book for the SBM switch was to be modified to advise against the use of hydrocarbon cleaning materials.

5.4 Aging Surveillance/Potential Monitoring Techniques

Megger or high pot testing to detect impending insulation breakdown or failure and periodic contact resistance measurements could be performed. This testing would detect the onset of insulation leakage currents or contact degradation and the need for action. This type of testing on a routine preventive maintenance schedule for all plant switches is not recommended since the time and effort involved to test the many low maintenance switches is not justified. However, if inspections reveal darkening of contact surfaces or pitting, high pot testing and contact resistance measurements are warranted to detect potential problems and trends for specific switches.

The SBM switch, as an example, is constructed with enclosed contacts and tight enclosures. Build up of dust and other contaminants has not been reported as a major problem area. Contacts should be cleaned when inspecting for contact burning, contact wipe, and broken shunts. The use of hydrocarbon cleaning materials is prohibited because of chemical reactions with the plastics. Cam follower crazing has been noted as an isolated manufacturing plant event, therefore periodic inspection for crazing or fracturing of the Lexan cam followers is not justified for all switches. However, monitoring of a small sample of switches is warranted to detect potential crazing or fracturing. For the SBM switch, this has been accomplished by inspecting for cracks with an auxiliary light source of adequate intensity through the opening near the terminals of each switch deck. Switch disassembly for this monitoring is not recommended.

6.0 SUMMARY AND APPLICATION GUIDE

This summary will apply the preceding analysis to demonstrate the qualification of a rotary hand switch for mild environment Class 1E service in nuclear power plants. An example is given for the Westinghouse PB series switch.

6.1 SBM Switch

Review and analysis of design, materials of construction, operating experience and test result data for the commercial grade General Electric SBM rotary hand switch reveals that for a mild environment application, design margins are sufficient for normal and abnormal plant operating conditions. The SBM switch has been tested for mild environment application to meet the IEEE Standard 323-1974 lifetime preconditioning requirements for functional testing, thermal aging, and radiation subject to the following:

a. With regard to manufacturer's specified ratings, the SBM switch is appropriately rated for the number of mechanical cycles to failure. It is conservatively rated or underrated for allowable temperature rise of the Lexan cam follower and is overrated for high inductive loading at 125 VDC.

b. Qualification has been based primarily on test with no failures noted during testing except at high values of inductive current loading. Where applications are limited to switching inductive loads $\leq$ 300 ma at 125 VDC the switch can be expected to perform its required functions over the design life.

c. To establish the on going qualification during operational life; surveillance and maintenance should be conducted as previously noted, i.e., periodic operational cycling, cleaning, and inspection for contact damage. A spare parts inventory should also be specified in the maintenance program.

6.2 GE CR2940 Switch

This switch is smaller in physical size and utilized extensively on the newer, more compact operator benchboards. The switch is qualified for mild environment operation to IEEE Standard 323-1974 by test, (reference 7.1.10).

6.3 L and N 8248-10 Switch

This switch is utilized for low voltage and current switching of thermocouple wire or low power control loops. The switch is qualified for mild environment operation to IEEE Standard 323-1974 by test, (reference 7.1.4).

6.4 Similarity Analysis for Mild Environment Qualification of Westinghouse PB Series Switch.

Similarity analysis is an important part of IEEE Standard 323-1974 environmental qualification documentation. This analysis is used for extrapolation of testing data from one model assembly to another similar product assembly.

The GE CR2940, SBM, L&N 8248-10, and Westinghouse PB series switches have been shown to be of similar design, materials, construction and application. Analysis verifies that these and similar switches can be applied in mild environments without the age testing of IEEE Standard 323-1974. The Westinghouse PB series switches are included within the qualified rotary hand switch subgroup by analysis of operational limits, material environmental degradation and design similarities.

Conclusions from the similarity analysis to follow, indicate that Westinghouse PB switch materials selected will allow a minimum 40 year operating life in a mild environment. Switch operating life will be based on contact cycling stress and limited to approximately the same period as the other switches. Establishing the design life will normally be performed by a manufacturers operating test at rated AC and DC loads in support of a certificate of compliance to the purchase specification discussed in Section 6.6.

a. Operational Similarity

Table 6-2 indicates an upper conservative internal operating temperature limitation from switch self heating of 100°C (212°F) ambient for Acetal (Delrin) plastic. The materials weak link analysis indicates a thermal activation energy which will yield a greater than 40 years material operating life by Arrhenius analysis. All the switches have similar operational contact cycle limitations and will be operational limited to a useful life dependent upon contact stress level and contact surveillance and maintenance renewal.

b. Design Similarity

These switches have a common design consideration for restraining the free movement of metallic parts subject to breakage. Contact springs or cam follower breakage will not short out other block contacts and contact position remains in place upon failure. Dielectric strength and contact voltage rating have ample margin from age degradation and retention of working elasticity for contact pressure.

c. Materials Similarity

Table 6-1 lists the switch materials.

The thermal aging analysis of subsection 3.5 indicates that the four subject switches are similar with respect to their susceptibility to thermal aging.

The cams, cam followers, contact blocks, and wafers are made of similar materials; Noryl, Phenolic, Lexan and Delrin. The internal device heating of these commercial grade materials will not result in significant degradation due to normal or abnormal operating temperatures in mild environments.

All of the devices are constructed with silver or silver-alloy contacts. Operating history indicates that the switches, with proper inspection and maintenance, have not experienced failure with contacts attributed to aging.

Application of these switches by other industries in rugged environments indicates that the switches, installed per vendor instructions, are structurally sound for nuclear power plant mild environment Class 1E application. No common mode of switch failure has been identified for the Westinghouse PB series switches. No material aging effects are identified by analysis or operating history to couple with seismic stress which are not identifiable through routine maintenance.

d. Surveillance and Maintenance Similarity

The four switches have similar surveillance and maintenance requirements described in section 5.0. The polycarbonate materials are susceptible to crazing from application of hydrocarbon cleaning agents. Proper cleaning agents and techniques will alleviate this potential problem.

6.5 Other Switches

Some other commercial grade switches in this device subgroup expected to fall under the umbrella of qualification are listed below. Analysis; with additional review of vendor test data, documentation of design and manufacturing processes and operating margins of materials, is expected to demonstrate their qualification.

- Micro Switch, Honeywell Division - Type RM/AS Series
- Cutler-Hammer - Type T Series
- Grayhill - Type 42A36
- GEMCO - Type SM and 404 Series
- General Electric - Type SB Series
- Westinghouse - Type W-2 Series
- Master Specialties - Type 2100 Series

6.6 Generic Class 1E Rotary Hand Switch Purchase Specification

a. Purpose

A purchase specification will delineate switch environmental and operating conditions which are required by the utility. If the specified environment falls within the limits of Table 6-2, the switch can be evaluated by similarity

The on-going qualification of equipment in a mild environment is dependent upon a documented surveillance and maintenance program such as described in section 5.0. Since the design life limiting factor is switch contact deterioration for many of the rotary hand switches, surveillance and maintenance scheduling will correspond to the contact stress level encountered.

Nominal switch contact stress level for Class 1E applications will allow at least 30,000 cycles between maintenance renewal. Indications of contact deterioration or other material stress degradation will appropriately shorten the maintenance interval.

b. Design and Qualification

A certificate of compliance by the manufacturer to the purchase specification operational and environmental conditions requires as complete a description of these conditions as possible.

The purchase specification should describe all the switch installation anticipated normal and abnormal cycling and environmental stresses. Anticipated installation conditions should be worse case location within a mild environment with an allowance of $10^{o}F$ additional rise in a panel. Range of environmental temperature, humidity, pressure and radiation should be given for the normal and abnormal conditions. Duration of the abnormal condition anticipated during plant life should be stated.

Switch worst case cyclic stress conditions for which the design life is established must be given. This should be 30,000 to 50,000 switch operations without maintenance per the manufacturers contact ratings. User anticipated switching load conditions should be given such as current, voltage, inductive and resistive loads.

Replacement switch designed operating cycle life should be equal to or greater than equipment it replaces. This is necessary to maintain the same design life of the panel within which it is installed.

Specific qualification, installation and maintenance documentation should be required from the manufacturer. The following is the minimum required technical support documentation for Class 1E rotary hand switch purchase and on-going qualification.

- Certificate of compliance that the equipment meets or exceeds the specified operating and environmental stress levels for the specified design life.

- Vendor Operating history and any subsequent design and material changes or substitutions for improvement.

- Instruction manual for maintenance and installation of the various contact configurations, escutcheon engravings and handle and detents being ordered by the purchase specification.

- Inspection and maintenance guidelines to ensure contacts will function for the switch lifetime and be replaceable as necessary.

- Suitable cleaning agents for removal of dust and contaminants.

c. Quality Assurance Program

Class 1E equipment purchased for essential service shall have a quality assurance program referenced by the equipment purchase specification. The quality assurance documentation is controlled by ANSI Standard N45.2 of Section 7.7. A Class 1E equipment suppliers minimum quality assurance documentation in support of qualification utilizing Regulatory Guide 1.89 mild environment guidelines are listed below.

- Quality control procedures to be followed during the manufacture and quality assurance testing.

- Quality assurance data sheets to be used during the production unit routine manufacturing acceptance testing.

- Materials identification list including traceability for aging analysis.

- Estimate of thermal aging based on testing, or similarity analysis with other materials or different molds of the same material.

- Analysis or test results to confirm that there is sufficient margin that rated loads will not result in excessive thermal stresses or operating temperature of critical components.

- Traceability by similarity analysis, serial number or lot number to testing at equal or greater stress levels.

Table 6-1

ROTARY HAND SWITCH COMPONENTS/MATERIALS OF CONSTRUCTION

Switch Components	Material Chemical (Name)	Thermal Activation Energy (Reference)	Radiation Threshold RADS (Reference)	GE SBM	GE CR2940	L&N 8248	W PB
Cams Caps Ring/Plates	Polyphenylene Oxide (Noryl)	.84 (7.1.10)	10^5 (7.2.3)		X		
Supports	Polyvinyl Chloride (Vinylite)	1.08 (7.2.5)	$>10^6$ (7.2.3)	X			
Contact Block Barriers Covers	Phenolic	.84 (7.2.5)	$>10^5$ (7.2.3)		X	X	
Seals Spacers	Acryloritrile-Butadient (Buna-N)	.84 (7.1.10)	10^7 (7.2.3)		X		
Positioning Wheel	Vulcanized Fiber	1.16 (7.2.5)	$>10^5$ (7.1.7)	X			
Contact Block Cam Follower Wafer	Polycarbonate (Lexan)	1.01 (7.2.5)	$>10^5$ (7.2.3)	X		X	
Cams	Acetal (Delrin)	.73 (7.2.5)	$>10^5$ (7.2.3)				X
Rings Plates	Polyester	.87 (7.2.1)	$>10^7$ (7.2.3)				X
Knobs Contact Block Handles	Polycarbonate	1.01 (7.2.5)	$>10^5$ (7.2.3)				X
Contacts	Silver Silver Alloy	N/A (N/A)	N/A N/A	X	X	X	X
Spacers Shafts Locks Springs Screws/Nuts Stops Knobs/Dials	Steel/ Aluminum Brass	N/A (N/A)	N/A (N/A)	X	X	X	X

Table 6-2

ROTARY HAND SWITCHES OPERATIONAL AND ENVIRONMENTAL LIMITS

PARAMETER	LIMIT	REPORT REFERENCE
Maximum Temperature for Switch Operation	100°C (212°F)	Subsection 3.1
Minimum Radiation Threshold for Degradation	10^5 RADS γ TID	Subsection 3.4
Lowest Activation Energy of Materials	0.73 ev	Table 6-1
Age Testing (Arrhenius Method)	40 years	Subsection 3.5
Cleaning Agents to Preclude Crazing	No Hydrocarbons	Subsection 5.3
Operational Cycles	>50,000 low inductive loading (Normal Application) >30,000 mid range inductive loading	Subsection 3.6

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7.3 Licensee Event Reports

	Plant	Date	LER No.
7.3.1	Peach Bottom 3	Jan. 75	75-7
7.3.2	FitzPatrick	Jan. 75	75-17
7.3.3	Hatch 1	May 75	75-37
7.3.4	Calvert Cliffs 1	May 75	75-37
7.3.5	Robinson 2	Nov. 75	75-18
7.3.6	Three Mile Island 1	Apr. 75	75-12
7.3.7	Hatch 1	Feb. 76	76-16
7.3.8	Ft. Calhoun 1	Feb. 76	76-2
7.3.9	Brunswick 1, 2	June 77	77-37
7.3.10	Davis Besse 1	Aug. 77	77-45
7.3.11	Davis Besse 1	Aug. 77	77-67
7.3.12	Oyster Creek	Dec. 78	78-33

7.3.13 Davis Besse 1	July 79	79-83
7.3.14 Brunswick 2	Oct. 80	80-90
7.3.15 Ft. Calhoun 1	Sep. 80	80-20
7.3.16 Rancho Seco 1	Apr. 80	80-22
7.3.17 San Onofre 1	Sep. 80	80-035
7.3.18 Brunswick 1, 2	Jan. 81	81-04
7.3.19 Millstone 2	Jan. 81	81-1
7.3.20 Sequoyah	Jul. 81	81-098
7.3.21 McGuire	Dec. 81	81-188

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7.5.2 Letter November 25, 1975; P. Thompson Commonwealth Edison to W. Jacquot, GE C and I FDI Engineering; Lasalle County Station Units 1 and 2 SBM Switches.

7.5.3 Letter July 9, 1981; D. N. Ekvall, Director QA, Leeds and Northrup to D. Mahon, Power Technical Associates; 8248 Switch.

7.6 Standards and Regulatory Guides

7.6.1 IEEE Standard 323-1974, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

7.6.2 IEEE Standard 381-1977, Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations.

7.6.3 U.S. NRC Regulatory Guide 1.89, Environmental Qualification of Electric Equipment for Nuclear Power Plants, Proposed Revision 1, February 1982.

7.7 American National Standards Institute (ANSI) Standards

7.7.1 ANSI Standard N45.2-1977, Quality Assurance Program Requirements for Nuclear Power Plants.

7.7.2 ANSI Standard N45.2.9-1974, Requirements for Collection, Storage, and Maintenance of Quality Assurance Records for Nuclear Power Plants.

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APPENDIX A
ROTARY HAND SWITCHES DESCRIPTION

The four models of rotary hand switches specifically addressed in this report are described in detail below. This information was used to summarize the common physical characteristics and functional requirements for the subgroup in Section 2.0.

General Electric SBM Switch

The General Electric SBM switch is a cam operated device having two mechanically and electrically separate contacts per stage. Separation is accomplished by means of two cams and two followers assembled with moving contacts. The SBM switches are normally used for the control of electrically operated devices such as circuit breakers; small motors and magnetic switches; and for the transfer of meters, relays and other instruments. Specific application includes transfer of control to Remote Shutdown Control Panels and selection of Reactor System modes. Figures A-1, A-2, and A-3 give an exploded and pictoral view of the SBM switch. Table 6-1 listed the component materials.

Each cam is constructed with two operating surfaces. These surfaces operate on the cam follower which has two tips located in offset horizontal planes lining up with the two cam operating surfaces. As the cam is rotated, one surface operates against the closing cam follower tip, while the opening tip is relieved. Both cam follower tips are always in contact with the cam surface allowing for a positive closing and opening action not dependent on springs.

Each cam follower has a spring loaded moving contact attached to it. A compression spring acts to give adequate contact pressure when a contact is closed. The moving contact is held to the cam follower by a pin passing through a hole in the cam follower at an angled slot in the moving contact. As the contacts close, the moving contact slides along this slot while compressing the spring thus causing relative motion or "wipe" between moving and stationary contacts.

Some applications, particularly of momentary contact switches which have a torsion spring to return the switch to a central-neutral position, require a contact action which lags behind the switch motion (lost motion or slip contacts). Such contacts use cams with a special loose fit on the shaft. When the shaft has turned far enough to close or open these contacts, it can be rotated 45 degrees in the reverse direction without moving the cams, but beyond this point, the cam moves with the shaft and the contacts either open or close.

Momentary contact switches have a torsion spring that returns the switch to a central or neutral position when the handle is released after operation to a right or left side position. This torsion spring is designed for maximum 90 degrees operation to each side of the central position. The torsion spring may have one end cut off or tied back in such a manner as to be effective on one side of the central position only. That is, the switch may have momentary contact to one side of the central position and maintaining contacts on the other side.

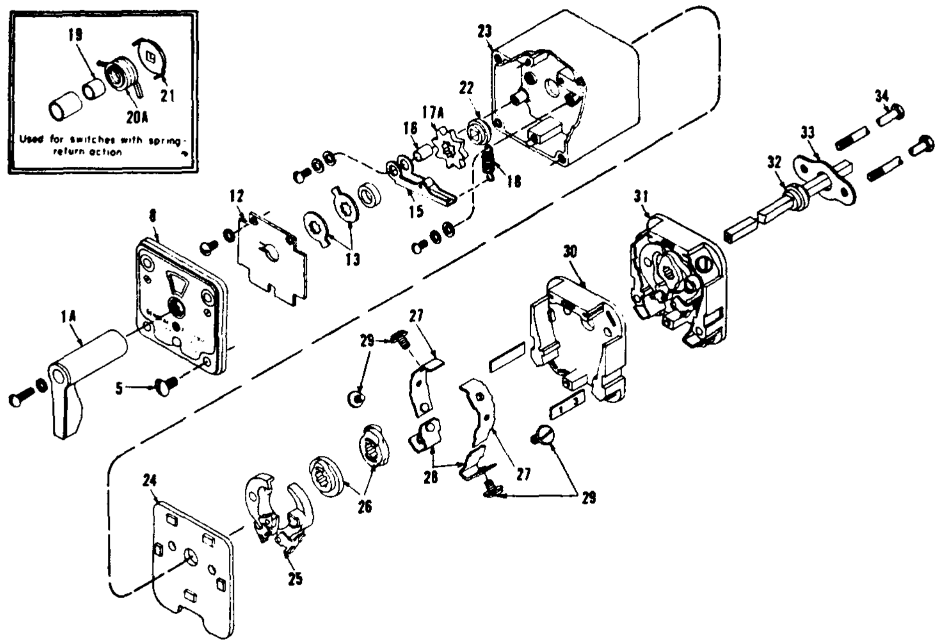
In some momentary contact (spring return) switches, a locking device is provided by which the shaft may be held against the action of the torsion spring by pulling out the handle when the switch is turned to one of the side positions.

A detent wheel, mounted on the square shaft and acted upon by a spring loaded roller arm, gives positive positioning action to the switch.

The SBM switch is rated for mechanical life of 500,000 (unloaded condition) operations. The electrical ratings are 600 volts ac or dc, 20 amps continuous or 250 amps for three seconds. The interrupting rating depends upon the voltage and character of the circuit. The table below illustrates the interrupting duty of a single contact and contacts in series when various conditions exist on a circuit.

INTERRUPTING RATINGS - AMPERES

CIRCUIT VOLTS	NON-INDUCTIVE CIRCUIT			INDUCTIVE CIRCUIT		
	NUMBER OF CONTACTS					
	1	2 in Series	4 in Series	1	2 in Series	4 in Series
24 d-c	6.0	30.0	——	4.0	20.0	30.0
48 d-c	5.0	25.0	40.0	3.0	15.0	25.0
125 d-c	2.7	11.0	25.0	2.0	6.25	9.5
250 d-c	0.75	2.0	8.0	0.7	1.75	6.5
600 d-c	0.25	0.45	1.35	0.15	0.35	1.25
115 a-c	40.0	75.0	——	24.0	50.0	——
220 a-c	25.0	50.0	——	12.0	25.0	40.0
440 a-c	12.0	25.0	——	5.0	12.0	20.0
550 a-c	6.0	12.0	——	4.0	10.0	15.0



Ref. No.	Catalog Number	Description
1A	888B208AAP1	Handle, fixed, pistol grip
†1B	888B208ABP1	Handle, fixed, oval
1C	888B208ACP1	Handle, fixed, knurled
†1D	6248034P2	Handle, fixed, lever
†2A	127A6780G1	‡Handle assembly, removable, standard
†2B	127A6780G3	‡Handle assembly, removable, engraved "R"
†2C	127A6780G4	‡Handle assembly, removable, engraved "T"
3	307V511P1	White pointer for handle
†4	307V516	Spring washer for pointer
5A	6049905P1	Mounting screw, 3/32 - 1/4 inch panel
5B	6049905P8	Mounting screw, 1 - 1 1/2 inch panel
6	NP-202491	Circuit designation plate (specify engraving)
7	127A6768P1	Escutcheon, fixed handle, no target (specify engraving)
8A	127A6757G1	Escutcheon, fixed handle, with target (specify engraving)
8B	127A6757G2	Escutcheon, fixed handle, with target ("TRIP" - "CLOSE")
8C	127A6757G3	Escutcheon, fixed handle, with target ("STOP" - "START")
8D	127A6757G4	§Escutcheon, fixed handle, with target (specify engraving)
8E	127A6757G5	§Escutcheon, fixed handle, with target ("TRIP" - "CLOSE")
8F	127A6757G6	§Escutcheon, fixed handle, with target ("STOP" - "START")
†9	888B207P1	‡Escutcheon, removable handle (specify engraving)
†10	127A6763P1	§Locking plate
†11	307V508P1	Shaft coupling (removable handle switches only)
12	127A6753P1	Front plate
13	127A6754P1	Stop wheel (standard)
†14A	127A6764G1	§Stop wheel and shaft assembly, 3/32 - 1/4 inch panel
†14B	127A6764G2	§Stop wheel and shaft assembly, 1-1 1/2 inch panel
15	127A6772G1	Roller arm assembly
16	6074939P91	Roller arm bearing sleeve
17A	127A6774P1	Index wheel, 8 points, 45 degree spacing
†17B	127A6774P2	Index wheel, 7 points, 45 degree spacing
†17C	127A6774P3	Index wheel, 4 points, 90 degree spacing
†17D	127A6774P4	Index wheel, 3 points, 90 degree spacing
*18	127A6781	Positioning spring
19	307V510P1	Torsion spring sleeve
*20A	127A6775P1	Torsion spring, standard (spring return CW and CCW)
*†20B	307V513P1	Torsion spring, special (spring return CCW to normal only)
*†20C	307V513P2	Torsion spring, special (spring return CW to normal only)
21	127A6760G1	Torsion spring actuator
22	127A6755P2	Front bearing
23	237C755P1	Front support
24	237C756P1	Barrier cover plate
*25	127A6770G1	Cam follower and moving contact assembly
26	237C759P(¶)	Cam
*27	127A6749G1	Stationary contact, upper
*28	127A6751G1	Stationary contact, lower
29	6047297P1	Connection screw
30	237C757P1	Intermediate barrier only (no contacts)
31	237C758P1	πRear support only (no contacts)
32	Δ	Rear bearing and shaft assembly
33	NP-202490	Rear bearing retainer and nameplate
34	127A6756G(◊)	Tie bolt

Figure A-1. Exploded View of SBM Switch

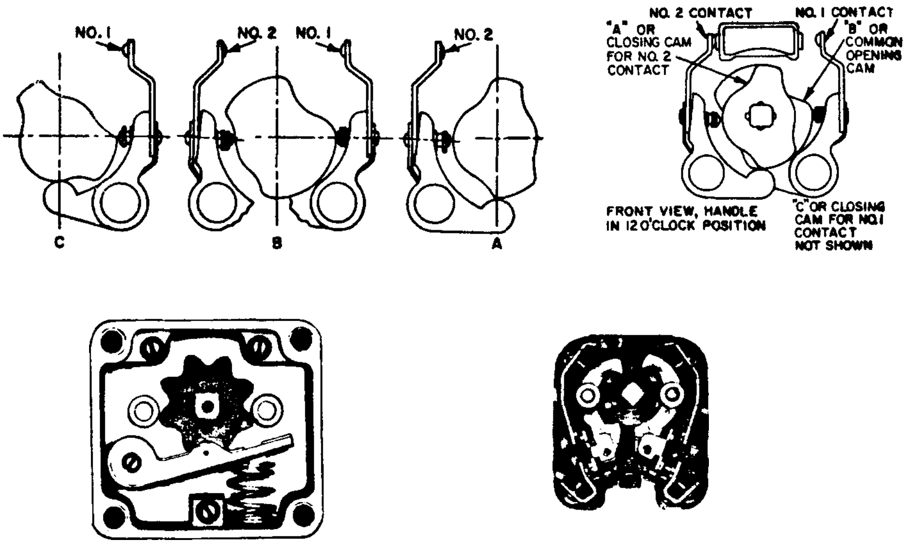


Figure A-2. SBM Contacts and Cams

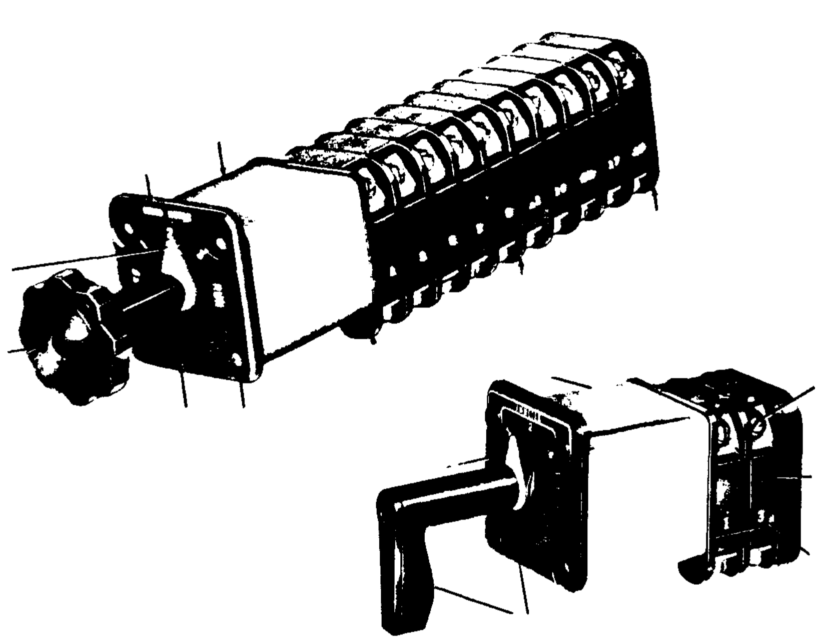


Figure A-3. Typical SBM Switch

General Electric CR2940 Switch

The General Electric CR2940 switch features high tip pressure, double break, silver contacts. Circuitry needs are met with two types of heavy-duty oil-tight contact blocks. The single-circuit design provides the basic 1-NO or 1-NC blocks which can be used to accommodate up to eight circuits, with any of 44 combinations including 8-NO and 8-NC contact arrangements. Panel-mounted units are available on double-circuit blocks with up to 4-NO/4-NC contact arrangements. Double-circuit blocks can be mounted in tandem. The GE CR2940 line of oil tight push button switches, can operate under severe industrial conditions where oil, water, coolants and/or other contaminants may be present. The switch is shown in Figure A-4. Materials of Construction were given in Table 6-1.

The CR2940 is rated for a mechanical life of 100,000 operations. The maximum contact voltage rating is 600 volts ac or dc. The table below illustrates the electrical ratings of the switch.

Circuit Volts	Carry Continuous Amps	Momentary Amps	Interrupting AC Cir. Amps	Capacity DC Inductive Amps
110-125	10	60	6.0	2.2
220-250	10	30	3.0	1.1
440-480	10	15	1.5	---
550-600	10	12	1.2	0.4

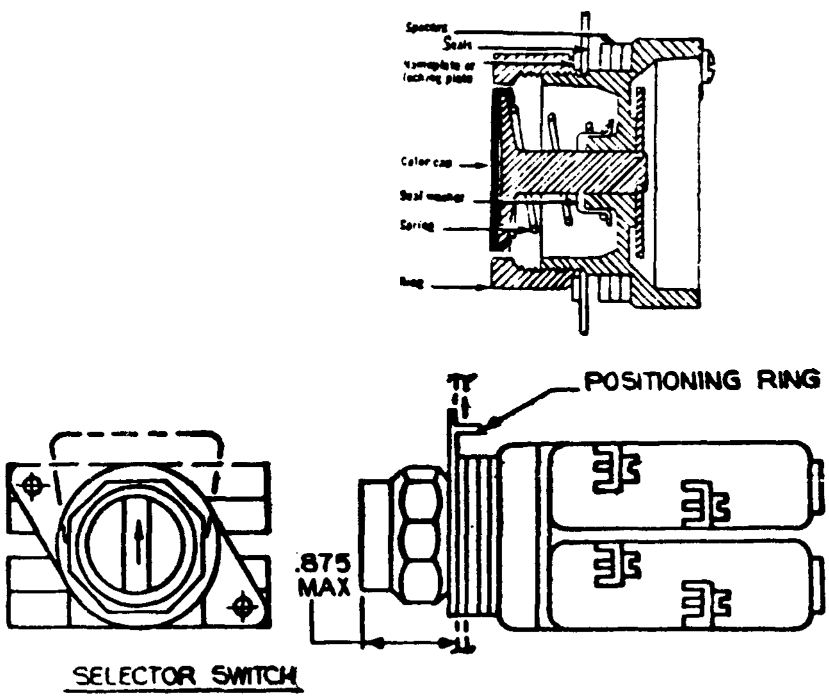
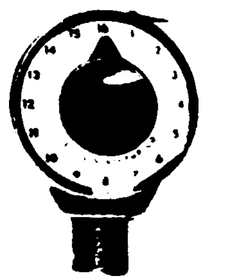


Figure A-4. General Electric CR2940 Switch

Leeds & Northrup 8248-10 Switch

The Leeds and Northrup double-pole, rotary-type assembly is used to connect a number of individual thermocouples successively to the same indicator. The switch is normally located in the Control Room. The 8248-10 Switch Assembly utilizes the Type 31-3 Switch. The 8248 Assembly, 31-3 Switch and component parts are shown in Figures A-5 and A-6. The selector switch component materials were listed in Table 6-1.

The switch silver-alloy contacts provide low thermal emf noise of less than 1 microvolt and contact resistance of less than 0.001 ohm, with variations of less than 0.0005 ohm. Assemblies can be flush-, surface-, or conduit-mounted. It is expected that the switch will be surface-mounted to a Control Room panel. The switch can be rotated in its housing to positions 90° apart so that conduit, if applicable, can extend from top, bottom, or either side. Switches having the acrylonitrile shaft are reported to be of higher quality than those with the phenolic shaft. The assembly size is approximately 3.7" face diameter, 4.2" high, and 5.5" deep.



8248 Switch Assembly

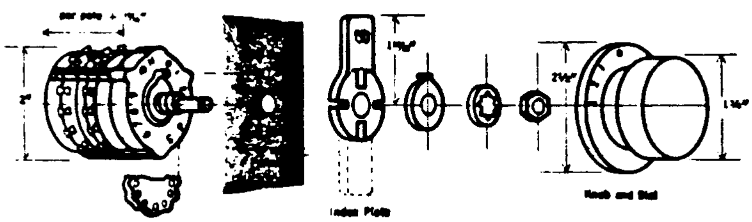


Figure A-5. Type 31 Switch

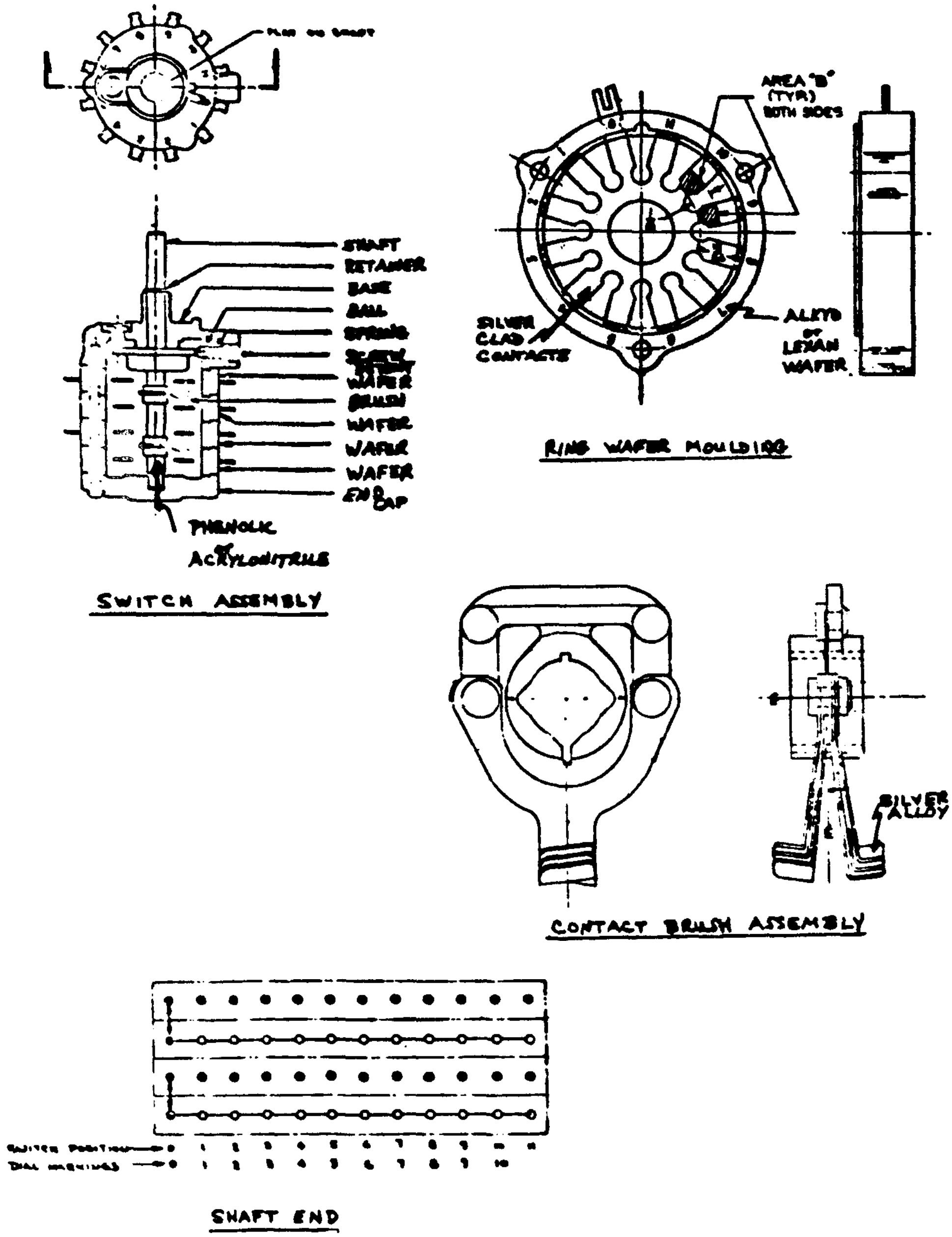


Figure A-6. L and N 8248-10 Switch

Westinghouse PB1/PB2 Switches

The Westinghouse PB2 selector switch is shown in Figure A-7. The switches are supplied with a choice of two, three, or four operating positions. If required, maintained operators can be field converted from two to three to four positions by changing the location of the operating knob in relation to the tube inside the housing. The PB2 is similar in design to the PB1 switch but is made of plastics for applications requiring corrosion resistance. The possible contact sequences are achieved with use of only one cam. The cam snaps in place on the rear of the housing. The materials of construction were given in Table 6-1.

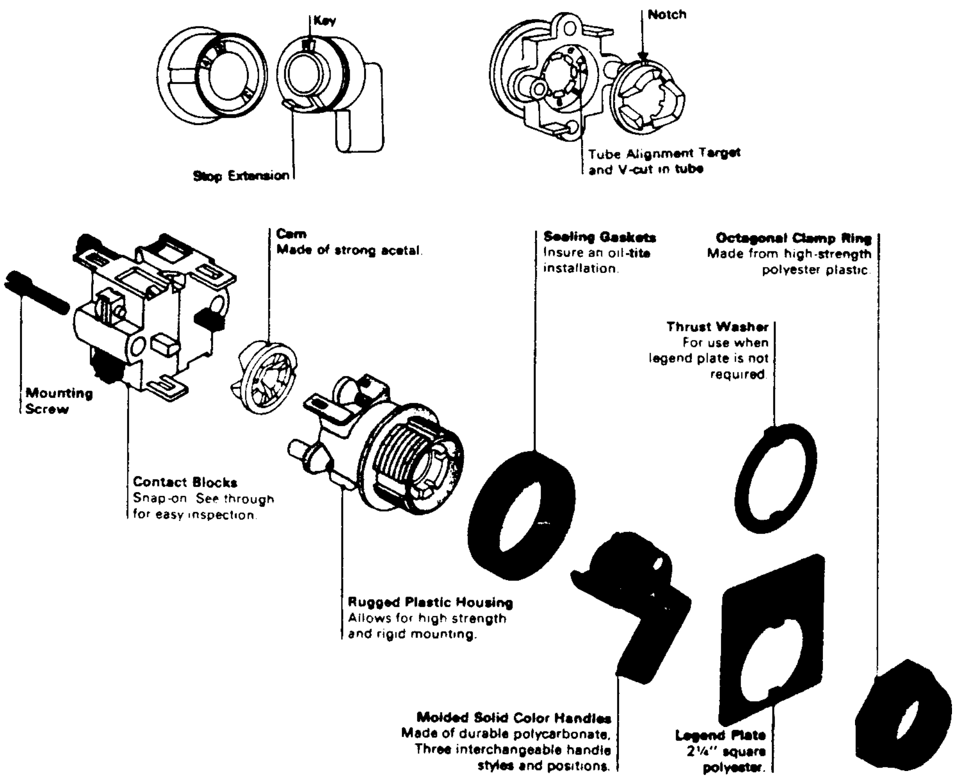


Figure A-7. Westinghouse PB2 Switch

APPENDIX B

SUMMARY OF AVAILABLE TEST DATA

The General Electric SBM switch has been in nuclear power plant installations for many years as a Class 1E device. Extensive testing has been performed over years of operating history with minimum changes to functional design and material selection. The number of years selected for useful life evaluation is dependent upon the number of full load operating cycles anticipated. Generally, switches required to transfer full load rating more than 5 times per day within the 50,000 cycles limit may not be acceptable for more than 10 years service. Switches operated infrequently are often useful for 40 years. The duration of useful life identified in the cases below is due to the testing specification for each case and does not imply a switch limitation.

SBM switches have been tested under various conditions to demonstrate their ability to perform their required functions under specified service conditions. The results of these tests are summarized below and in Table B-1.

Case 1: Reference 7.1.5 reported results of qualification tests on the SBM switch. During the mechanical cycling testing sequence, SBM contacts were not capable of handling the manufacturer rated inductive load of 4 amps at 125 VDC. This load caused welding of the contacts at 2 cycles on the test specimens. When the load was reduced to 2 amps inductive @ 125 VDC, failures were observed at 29,000 cycles. These failures indicate the contacts are overrated for inductive loads at 125 VDC. Other tests performed on the mechanically aged items during this sequence included thermal aging followed by functional testing. These tests indicated the SBM switches were not adversly affected by temperature, seismic, and mechanical aging which simulated the forty year installed life of the devices.

Case 2: Reference 7.1.7 reported results of a qualification test of the SBM switch which included mechanical, thermal and radiation aging for an installed life of 10 years. The switch was also subjected to a design basis accident environment test. There were no failures or degradations noted as a result of these tests. However, the switch contacts were not loaded during this testing to simulate a functional test.

Case 3: Reference 7.1.9 reported testing of an SBM switch for 10,000 cycles @ 460 Volts AC, 20 amps resistive load and 25,000 cycles @ 460 Volts AC, 12 amps reactive load. These values were in excess of the 12 amp & 5 amp ratings of the switch however very little contact wear or deterioration of insulation occurred. There were no mechanical failures resulting from the 35,000 operation cycles.

Case 4: Reference 7.1.8 reported results of 50,000 cycles of SBM operation with inductive and non-inductive loads of 300 MA @ 600 Volts DC, or 8 Amps @ 600 Volts AC. This testing established an acceptable DC inductive current rating for the SBM switch and also indicated mechanical cycling stress does not produce failures of this switch.

Case 5: Reference 7.1.11 reprorted results of qualification testing of an SBM switch which included thermal, radiation level and mechanical cycling (50,000) to simulate 40 year life prior to seismic testing. The switch remained operational during and after the seismic test indicating the switch is not subject to failure induced by mechanical cycling or thermal or radiation aging. No information was given regarding contact loading during this test.

Case 6: Reference 7.1.6 indicates SBM switch tested to verify capability of handling 130 MA inductive load @ 125 VDC.

Case 7: Reference 7.1.3 reported that an SBM switch is capable of continuously carrying maximum 20 AMP rated current without the associated temperature rise exceeding the allowable rise for the cam follower material (Lexan).

Case 8: Reference 7.1.1 reports that an SBM switch underwent complete IEEE 323-1974 environmental qualification testing. This included aging at 100^{o}C (212^{o}F) to a 10 year qualified life, a 15,000 cycle test, functional testing at device ratings, and seismic testing.

Summary Cases 1 through 8

The available test data supports the following conclusions:

a. Failure modes are not induced in SBM switches due to thermal, radiation or mechanical cycling stress factors for an installed life of 40 years.

b. SBM switch contacts are overrated for inductive loads at 125 volts DC.

c. SBM switch contacts are appropriately rated for AC resistive and inductive loads.

d. Where applications are limited to switching inductive loads $\leq$ 300 mA at 125 VDC, the SBM switch can be expected to perform its required functions over an installed life of 40 years. Normal application is in the range of 130 mA at 125 VDC. Note that higher DC inductive load currents can be interrupted to solenoids with MOV shunts installed. However, the installation of contact protecting MOV shunts introduces another potential failure mechanism. Present development of metal oxide varistors (MOV's) indicate operational frequency for only ten years. The MOV failure is normally an open circuit with the interrupting burden transferred to the switch contacts.

e. Capacitive load interruption by the switch presents an increasing voltage gradient from contacts to mounting ground, but is not a problem with the high insulation characteristics of the assembly plastics. Closing on a capacitive load causes large inrush currents of insufficient duration to damage contacts, but will burn clear any accumulated contact residue.

Table B-1

SUMMARY OF SBM TEST DATA

Test Case #	No. Mech Cycles	Thermal Aging Duration	Thermal Aging Temp	Radiation TID	Radiation Type	Contact Loading Volts	Contact Loading AMPS	Seismic	Notes
1	50,000	32 Days 2 Days	115°C (239°F) 38°C (100°F)	None		125 VDC	2/4 Ind	5 OBE + 3SSE ZPA = .96V ZPA = 2.6H 1-40Hz Biaxial	1,2,4
2	3,700	100 Days 30 Days 100 Days	85°C (185°F) 50°C (122°F) 66°C (150°F)	$4x10^5$ Rads	γ	None	None	5OBE + 1SSE 12g Peak 10 Hz 1-40 Hz Biaxial	3,4
3	10,000 25,000	--- ---	--- ---	--- ---		460 AC 460 AC	20 Res 12 Ind	--- ---	
4	50,000	---	---	---		600 DC 600 DC 600 AC	300mA Ind 400mA Res 8 A Ind	5-30 Hz 10g Peak	5
5	50,000	48 Days 30 Days 100 Days	115°C (239°F) 50°C (122°F) 66°C (150°F)	$4x10^5$ Rads	γ	---	---	5 OBE + 1SSE Biaxial	1,4
6	---	---	---	---		125 VDC	130mA Ind	---	
8	15,000	32 Days	100°C (212°F)	---					

Notes:

1. To simulate 40 year life @ 24°C (75°F).
2. Various contact failures at 2/4 Amps inductive before 50,000 cycles completed.
3. Aging estimated for 10 year life @ 21°C (70°F).
4. LOCA/DBA temperature test was performed.
5. Contacts not energized during seismic tests.