| | |
|---|---|
| Document Level: | Functional Series |
| Document Number: | **Criterion 505 R2** |
| Approval Date: | 09/20/2010 |
| Effective Date: | 10/20/2010 |
| Supersedes: | Criterion 505 R1 |

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

## TITLE: STORED EMERGENCY POWER SUPPLY SYSTEMS

| Name | Organization | Date | Signature |
|---|---|---|---|
| **Criterion Author:** | | | |
| Duane E. Nizio<br>Maintenance Manager | MSS-MP | 09/20/10 | Signature on File (mm) |
| **Approved by:** | | | |
| Greg Melton<br>Group Leader | MSS-MP | 09/20/10 | Signature on File (mm) |
| Charles Anderson<br>NHHO Deputy<br>Associate Director | ADNNHO | 09/20/10 | Signature on File (mm) |
| **Issuing Authority:** | | | |
| Susanne Waylett<br>MSS Division Leader | MSS-DO | 09/20/10 | Signature on File (mm) |

**DUSA CLASSIFICATION STATEMENT**

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

**Documents intended for public release must still be processed through the publication release section of the Classification Group.**

# RECORD OF REVISIONS

| Revision No. | Date | Description |
|---|---|---|
| 0 | 09/10/98 | Initial Issue. |
| 1 | 1/15/02 | This revision reflects a review of ORPS & NRC lessons learned from 1/1/96 to 8/1/2001 and incorporation of the latest format of Criterion 101 Revision 3 of the Writer's Guide. |
| 2 | 9/30/2010 | This revision also includes the incorporation of all formatting changes addressed in Revision 3 of the O&M Criterion 101 Writer's Guide. This revision reflects current organizational structure and responsibilities, corrections, clarifications and examples. Changed the document name and terminology to align with the relevant standards. Deleted references to ML levels. |

# TABLE OF CONTENTS

# CRITERION 505

# STORED EMERGENCY POWER SUPPLY SYSTEMS

## 1.0 PURPOSE

The purpose of this Criterion is to establish the minimum requirements and best practices for operation and maintenance of Stored Emergency Power Supply Systems (SEPSS, formerly known as uninterruptible power supplies) at LANL. There are over 100 facility-level SEPSS at the Los Alamos National Laboratory protecting emergency lighting systems, life-safety systems, and critical instrumentation. (There are hundreds more standalone emergency power supplies, not covered by this Criterion, associated with users' equipment like desktop computers, data collections, etc.) Systems range in capacity from 400 VA to 1670 kVA. While the majority of SEPSS are of the static type, the higher capacity systems are of the rotary type.

The maintenance of SEPSS in accordance with this standard will ensure that power is available for critical loads or safety class loads used to protect health and safety of the public, workers, the environment and to reduce the consequences of postulated events involving nuclear, chemical, or other hazards or having adverse impact on the LANL mission.

SEPSS represent a sizable investment in equipment specifically installed to provide reliable regulated power to critical equipment and systems. Therefore, it is essential that SEPSS be maintained so that the SEPSS itself will not fail.

A review of DOE Occurrence Reports from FY 1995 through FY2000 filtered for "electrical equipment" then for "UPS" yielded 87 occurrences that were categorized and ranked in the following order:

| | | |
|---|---|---|
| • Battery failure | 36 | 41.4% |
| • Electronic component failure | 6 | 18.4% |
| • Maintenance personnel error | 7 | 8.0% |
| • External event (lightning, cooling, etc.) | 5 | 5.7% |
| • Poorly written procedure | 4 | 4.6% |
| • Circuit breaker or fuse failure | 3 | 3.4% |
| • Old, obsolete equipment | 3 | 3.4% |
| • Undetermined cause | 3 | 3.4% |
| • Clogged cooling fan or filter | 2 | 2.3% |
| • Cable connection failure | 2 | 2.3% |
| • Bypass switch failure | 2 | 2.3% |
| • Control switch or indicator light failure | 2 | 2.3% |
| • Inadequate design of SEPSS equipment | 1 | 1.1% |
| • Inadequate operator training | 1 | 1.1% |

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

## 2.0 SCOPE

The scope of this Criterion includes the routine inspection, testing and preventive and predictive maintenance of Level 1 and Level 2 SEPSS (as defined in NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*) of all sizes, at all nuclear and non-nuclear LANL facilities. This Criterion does not address corrective maintenance actions required to repair or replace equipment.

Proper testing and maintenance of SEPSS batteries is fundamental to a reliable SEPSS. This Criterion does not address in detail the operation and maintenance of battery systems that may be an integral component of a SEPSS. These issues are addressed within Criterion 511, *Stationary System Batteries*.

Proper testing and maintenance of the motor/generator components of rotary SEPSS is fundamental to the reliability of those systems. This Criterion does not address in detail the operation and maintenance of rotating equipment. They are addressed within Criterion 510, *AC Motors,* Criterion 506, *Generators* and in NFPA 70B.

Proper testing and maintenance of the circuit breakers in SEPSS is essential to the safety and reliability of the systems. This Criterion does not address in detail the operation and maintenance of circuit breakers. They are addressed within Criterion 504, *Low Voltage Electrical Equipment.*

This maintenance standard applies to all NFPA 111 Level 1 and Level 2 SEPSS.

Systems covered in this standard include static SEPSS, rotary SEPSS, and static bypass switches. Limits of system coverage are from the SEPSS and bypass AC input circuit breaker(s) through the output circuit breaker of the SEPSS.

This standard does not cover the design, selection, installation, or acceptance testing of SEPSS. This standard does not cover input or output distribution systems, wiring or switchgear. Refer to DOE-STD-3003, NFPA-70, NFPA-111, ANSI/IEEE 944, and the LANL Engineering Manual for requirements and guidance in these areas.

This standard does not cover the assignment of a Management Level to any specific SEPSS; refer to AP-341-502, *Management Level Determination,* for guidance.

This standard does not cover the maintenance of small “commodity” emergency power supplies dedicated to individual personal computer stations unless the application puts the system in Level 1 or Level 2 as defined in NFPA 111.

# 3.0 ACRONYMS AND DEFINITIONS

## 3.1 Acronyms

| | |
|---|---|
| AC | Alternating Current |
| AHJ | Authority Having Jurisdiction |
| ANSI | American National Standards Institute |
| CFR | Code of Federal Regulations |
| DC | Direct Current |
| DOE | Department of Energy |
| DSA | Documented Safety Analysis |
| FOD | Facility Operations Director |
| HVAC | Heating, Ventilating, and Air Conditioning |
| IEEE | Institute of Electrical and Electronics Engineers |
| kVA | Kilovolt-Ampere |
| LANL | Los Alamos National Laboratory |
| ML | Management Level |
| MM | Maintenance Manager |
| MP | Maintenance Programs |
| MSS | Maintenance & Site Services |
| MTS | Maintenance Testing Specifications |
| NETA | InterNational Electrical Testing Association |
| NFPA | National Fire Protection Association |
| NRC | Nuclear Regulatory Commission |
| OM | Operations Manager |
| ORPS | Occurrence Reporting and Processing System |
| PM | Preventive Maintenance |
| RMS | Root Mean Square |
| RPM | Revolutions Per Minute |
| SEPSS | Stored Emergency Power Supply Systems |
| SSC | Structures, Systems, and Components |
| TSR | Technical Safety Requirements |
| VA | Volt-Ampere |

## 3.2 Definitions

**AC Input-** Electric power in the form of alternating current (AC) supplied to the SEPSS and bypass. (IEEE Std 944, 1986, part 2)

**AC Input Failure Test-** A test performed by interrupting the AC input power or simulated by switching off all SEPSS rectifiers and bypass feeders at the same time. This test is performed with the DC source available. Output voltage and frequency variations are checked to be within specified limits. (IEEE Std 944, 1986, section 7.4.3)

**AC Input Return Test-** A test performed by restoring the AC input power or simulated by switching on all SEPSS rectifiers and bypass feeders at the same time. The SEPSS rectifier is observed for proper operation. Output voltage and frequency variations are checked to be within specified limits. (IEEE Std 944, 1986, section 7.4.3)

**Acceptance Test-** A capacity test made on a new SEPSS installation to determine that it meets applicable codes, specifications, and manufacturer's ratings.

**Battery-** A device that transforms stored chemical energy into electric energy. SEPSS batteries are typically rated at 15 minutes with an end cell voltage of 1.67 volts per cell, whereas a telecommunications battery (for example) is rated at 8 hours with an end cell voltage of 1.75 volts per cell. While a SEPSS battery is a short duration battery with a high rate of discharge, a telecommunications battery is a long duration battery with a lower rate of discharge. (IEEE Std 944, 1986, part 2)

**Battery Charger-** A device that can maintain a unidirectional current in a battery in the opposite direction to that during discharge thereby converting electric energy into chemical energy within the battery.

**Class-** The minimum time, in hours, for which the SEPSS is designed to operate at its rated load without being recharged. (NFPA 111, Table 4.3)

| | |
|---|---|
| Class 0.033 | 0.033 hours (2 minutes) |
| Class 0.083 | 0.083 hours (5 minutes) |
| Class 0.25 | 0.25 hours (15 minutes) |
| Class 1.5 | 1.5 Hours (90 minutes) |
| Class x | Other time, in hours, as required by the application, code, or user |

**Harmonic-** The sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency. (IEEE Std 944, 1986, part 2)

**Harmonic-Components Test-** A test in which the harmonic components of the output voltage are recorded under rated linear (sine wave) and nonlinear load conditions. (IEEE Std 944, 1986, section 7.4.11)

**Inverter-** A system that changes direct-current power to alternating-current power. (IEEE Std 944, 1986, part 2)

**Light Load Test-** A test of the SEPSS that is performed with normal loads connected to verify that the SEPSS is properly connected and that all functions operate properly. (IEEE Std 944, 1986) The following tests are included:

1. Measure and record SEPSS output voltage and frequency.
2. Check the operation of all control switches, measuring devices, meters, and other means required to determine proper SEPSS operation.

**NFPA 111 Level-** The level of equipment installation, performance, and maintenance shall be based on consequence of failure of the SEPSS, as defined by NFPA 111.

NFPA 111 Level 1 systems shall be installed where failure of the equipment to perform could result in loss of human life or serious injuries. Typically, Level 1 systems are intended to automatically supply illumination, power, or both, to critical areas and equipment in the event of failure of the normal supply, or in the event of damage to elements of a system intended to supply, distribute, and control power and illumination essential for safety to human life. (NFPA 111, Sections 4.5.1)

NFPA 111 Level 2 systems shall be installed where failure of the SEPSS to perform is less critical to human life and safety. Typically, Level 2 systems are intended to supply power automatically to selected loads (other than those classed as emergency systems) in the event of failure of the normal source. (NFPA 111, Sections 4.5.2 and A-2-2.5.2, and P950 *Conduct of Maintenance.)*

**Nonlinear Load-** A load with such characteristics that with an applied sinusoidal voltage the load current is not sinusoidal. (IEEE Std 944, 1986)

**Output Voltage-** The root-mean-square (RMS) voltage between the output terminals.

**Output Voltage Balance Test-** A test of three-phase SEPSS in which the phase-to-phase and phase to neutral output voltages are recorded during the following conditions:

1. Symmetrical load conditions
2. Unbalanced load conditions from no load to full load.

Phase angle deviations are either measured or derived by calculation from the values of phase-to-phase and phase-to-neutral voltages. (IEEE Std 944, 1986)

**Rectifier-** A device that changes alternating-current power to direct-current power to supply input power to an inverter but not to a battery. (IEEE Std 944, 1986)

**Safety Class-** Safety-class SSCs are systems, structures, or components whose preventive or mitigative function is necessary to keep hazardous material exposure to the public below the offsite Evaluation Guidelines. This definition would typically exclude items such as primary environmental monitors and most process equipment. (DOE-STD-3009)

**Static Bypass Switch-** A high-speed solid-state switch, usually internal to the SEPSS, that will automatically operate during an overload or in case of a fault in the SEPSS. The SEPSS is effectively removed from the circuit and the load is connected directly to the AC input.

**Stored Emergency Power Supply System (SEPSS)-** A system that converts unregulated input power into voltage and frequency controlled, sinusoidal wave AC power that continues without interruption for a finite period of time, even with the deterioration of the AC input power. (IEEE Std 944, 1986, part 2) A SEPSS may consist of one or more SEPSS modules connected to obtain the required capacity, to provide added reliability through redundancy, or both.

**Synchronization-** Bringing one AC power source of the same nominal frequency as another into the same frequency and phase angle of the other in order to avoid excessive current flow when paralleling the two AC power sources. (DOE –STD-3003-2000)

**Synchronization Test-** A test performed on SEPSS for which synchronization with an alternate source is required. Variation frequency limits are tested using a variable frequency generator. The rate of change of frequency during synchronization and the SEPSS output voltage are measured. (IEEE Std 944, 1986, section 7.4.2)

**Transfer Test-** A test performed on SEPSS that have a static bypass switch. Transients, such as maximum and minimum voltages, and transfer times are measured during load transfer to and from the bypass source. (IEEE Std 944, 1986)

**Type-** The maximum time, in seconds, that the SEPSS will permit the terminals of the transfer switch to be without acceptable electrical power. (NFPA 111 Section 4.2)

Type 0: No interruptions- SEPSS carrying load, 0 seconds.

Type U: Basically uninterruptible SEPSS with utility as preferred source.

## 4.0 RESPONSIBILITIES

### 4.1 MSS-Division Leader (MSS-DL)

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

### 4.2 MSS- Maintenance Programs (MSS-MP)

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

### 4.3 Facility Operations Director (FOD)

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

### 4.4 Operations Manager (OM)

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

### 4.5 Maintenance Manager (MM)

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

### 4.6 Authority Having Jurisdiction (AHJ)

The AHJ is the Point of Contact for the Electrical Chapter of the LANL Engineering Manual. The AHJ is responsible for providing decisions on specific technical questions regarding the systems or equipment relevant to this Criterion. The AHJ is also responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

## 5.0 PRECAUTIONS AND LIMITATIONS

### 5.1 Precautions

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

#### *5.1.1 Unintentional Interruption*

It is important to avoid unintentional interruption of the power output of the SEPSS. Extreme caution should be used when servicing the system to prevent unscheduled outages. SEPSS maintenance should be scheduled at times that will least affect operations. Actual maintenance procedures should not be started until the users have been notified. (Research of 87 DOE ORPS reports describing SEPSS occurrences from FY1995 through FY2000 revealed that SEPSS operating and switching errors by maintenance personnel were the third leading cause of SEPSS occurrences.)

*Basis:* NFPA 70B, section 22-2.1

#### *5.1.2 Personnel Qualification*

Only fully qualified personnel with proper test equipment, special tools and personal protective equipment should be authorized to perform SEPSS maintenance.

*Basis:* P 101-13 and NFPA 70E

#### *5.1.3 Lockout/Tagout Procedure*

A specific lock-out/tag-out procedure should be developed for the maintenance of each SEPSS. SEPSS present a special lock-out/tag-out challenge for the reasons outlined below.

*Basis:* P 101-3, *Lockout/Tagout for Hazardous Energy Control*

##### *5.1.3.1 Hazardous Energy*

Even with the SEPSS cabinet power switches off, hazardous electrical energy may remain inside the cabinet of a SEPSS. There are often multiple sources of electrical energy to a SEPSS cabinet. External disconnects or circuit breakers should be used to

completely isolate the SEPSS cabinet from AC and DC power sources. Capacitors within the SEPSS can retain hazardous electrical charge. They should be discharged and checked by a qualified person. The SEPSS batteries may be within the cabinet, and dangerous DC energy can exist when all external power has been disconnected.

#### *5.1.3.2 Rotary SEPSS Hazards*

A rotary SEPSS contains electrical hazards like a static SEPSS plus mechanical hazards such as rotating shafts, belts, and pulleys. After switching off a rotary SEPSS, the machine should be allowed to come to a complete standstill. A rotary SEPSS can generate hazardous voltage even when spinning at low RPM.

#### *5.1.3.3 Equipment-specific Maintenance*

SEPSS maintenance is very equipment-specific. The manufacturer's instructions should be followed carefully when performing maintenance on SEPSS equipment.

*Basis:* NFPA 70B, section 22-1

#### *5.1.3.4 Grounding and Fuses*

The integrity of the grounding system must be maintained as required by Article 250 of the National Electrical Code. Most SEPSS are separately derived systems. For separately derived systems, ascertain that the neutral is properly grounded.

*Basis:* NFPA 70B, section 22-2.1.8

SEPSS are generally protected with special fuses. Installing an improper fuse in a SEPSS can result in severe damage to the SEPSS and the load equipment. It is especially important that an ample supply of the proper types and sizes of spare fuses be maintained. Replace fuses only with fuses having the same or lower current ratings and the same types.

*Basis:* NFPA 70B, section 22-2.2.3

### 5.2 Limitations

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

Nuclear facilities and moderate to high hazard non-nuclear facilities will typically have additional facility-specific requirements beyond those presented in this Criterion. Nuclear facilities should implement the requirements of DOE Order 433.1B, *Maintenance Management Program for DOE Nuclear Facilities* as the minimum

programmatic requirements for a maintenance program. Additional requirements and recommendations for SSC operation and maintenance may be necessary to fully comply with the current DOE Order or the Code of Federal Regulations (CFR) as applicable.

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

## 6.0 REQUIREMENTS

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

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

### 6.1 Operations Requirements

#### *6.1.1 Documentation*

##### *6.1.1.1 Instruction Manuals for Both Level 1 and Level 2 SEPSS*

At least two sets of instruction manuals for the SEPSS shall be supplied by the manufacturer of the SEPSS and shall contain the following:

1. A detailed explanation of the operation of the system
2. A schematic wiring diagram
3. A function block diagram

4. The energy storage device's specification, installation instructions, maintenance information, and wiring diagrams
5. Instructions for routine maintenance
6. Recommended spare parts list with part numbers and part sources
7. Routine troubleshooting procedures

If manufacturer's documentation is not available for existing systems, the system owner must locate the information specified above, or apply for a variance to this requirement. The variance process (as described in section 6.0 of this document) can be used to establish compensatory measures on a case by case basis.

*Basis:* NFPA 111, section 8.2.1

A set of instructions manuals shall be kept with the SEPSS. The second set shall be kept in a secure location.

*Basis:* NFPA 111, section 8.2.2

## 6.2 Maintenance Requirements

### *6.2.1 General*

#### *6.2.1.1 Maintenance*

The SEPSS shall be maintained so that the system is capable of supplying the service quality within the time specified for the type and for the time duration specified for the class.

*Basis:* NFPA 111, section 8.3.1

#### *6.2.1.2 Routine Maintenance and Operational Testing*

A routine SEPSS maintenance and operational testing program shall be initiated immediately following initial acceptance, or following any repair or component replacement, including batteries.

*Basis:* NFPA 111, section 8.3.2

### *6.2.2 Personnel Qualifications*

Properly qualified personnel shall perform maintenance on SEPSS.

*Basis:* P 101-13, *Electrical Safety Program*

### 6.3 Preventive Maintenance

#### *6.3.1 Monthly Intervals*

##### *6.3.1.1 NFPA 111 Level 1 Systems*

Inspect/maintain each NFPA 111 Level 1 SEPSS monthly. Take corrective action for any item found to be deficient. Each inspection shall include the following:

1. Check and record the float voltage.
2. Check and record individual cell voltages where practical. (Refer to Criterion 511, *Stationary System Batteries* for additional requirements and recommendations.)
3. Check and record the specific gravity of pilot cells where applicable. (Refer to Criterion 511, *Stationary System Batteries* for additional requirements and recommendations.)
4. Note the condition of the plates and sediment of free-electrolyte, lead-acid batteries in transparent containers. (Refer to Criterion 511, *Stationary System Batteries* for additional requirements and recommendations.)
5. Perform a load test. Record the SEPSS output voltage, the battery voltage, and the duration of the test at the beginning and end of the test.
6. Check that all indicator lamps, meters, and controls are operating correctly.

*Basis:* NFPA 111, section 8.4.1

## 7.0 RECOMMENDED AND GOOD PRACTICES

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

### 7.1 Operations Recommendations

#### *7.1.1 General*

##### *7.1.1.1 Additional Loads*

Whenever additional loads are connected to the SEPSS, check the protective device coordination, calibration, and proper operation of the modified system. Perform light load test and harmonic components test.

*Basis:* NFPA 70B, section 22-2.2.8

##### *7.1.1.2 Inspection Intervals*

Intervals for recommended operational inspection should take into consideration the type of service to which the SEPSS is subjected (duty cycle, chemicals, dust, heat), manufacturer's recommendations, and trending.

*Basis:* DOE-STD-3003, section 5.3.2.

### *7.1.2 Personnel Qualifications.*

Specific qualification for SEPSS operation personnel should include the following:

1. Fundamentals of electrical and electronic design of SEPSS
2. Testing and maintenance practices for SEPSS
3. Safety precautions for SEPSS
4. LANL Electrical Safety Training per P 101-13, *Electrical Safety Program*

*Basis:* DOE-STD-3003, section 5.3.2.1

### *7.1.3 Weekly Intervals*

#### *7.1.3.1 External Visual Check*

SEPSS should be visually checked externally weekly. The SEPSS should be checked for evidence of problems by evaluating meter readings, sounds, odors, and detrimental environmental problems like heat, moisture, and chemicals.

#### *7.1.3.2 Lamps*

All lamps should be checked using the “lamp test” feature.

*Basis:* IEEE 446, section 8.5

#### *7.1.3.3 Meters*

All meters should be checked to ensure they are operating.

*Basis:* IEEE 446, section 8.5

#### *7.1.3.4 Readings*

Meter readings should be recorded: voltmeter, ammeter, and frequency at input and output.

*Basis:* NFPA 70B, section 22-2.1.7(b)

#### *7.1.3.5 Disturbance Monitors*

Operational status of the disturbance monitor should be verified, if the SEPSS is so equipped.

*Basis:* IEEE 446, section 8.5

#### *7.1.4 Monthly Intervals*

##### *7.1.4.1 Cleanliness and Housekeeping*

The appearance and cleanliness of all SEPSS equipment and the SEPSS room/area should be checked.

*Basis:* IEEE 446, section 8.5

##### *7.1.4.2 HVAC*

The SEPSS room/area HVAC equipment should be checked and the room/area temperature and humidity should be measured.

*Basis:* IEEE 446, section 8.5

##### *7.1.4.3 Intakes and Exhausts*

All SEPSS equipment air intakes and exhausts, including filters, should be checked.

*Basis:* IEEE 446, section 8.5

#### *7.1.5 Bi-Annual Intervals*

##### *7.1.5.1 Manufacturer Recommendations*

SEPSS manufacturer should be contacted for information on equipment upgrades and recommended revisions.

*Basis:* NFPA 70B, section 22-2.1.11

##### *7.1.5.2 Alarm Functions*

All alarm shutdown functions should be verified.

*Basis:* IEEE 446, section 8.5

### 7.2 Maintenance Recommendations

#### *7.2.1 Personnel Qualifications*

Specific qualification for SEPSS maintenance personnel should include the following:

1. Fundamentals of electrical and electronic design of SEPSS
2. Testing and maintenance practices for SEPSS
3. Safety precautions for SEPSS
4. LANL Electrical Safety Training per P 101-13, *Electrical Safety Program*

*Basis:* DOE-STD-3003, section 5.3.2.1

#### *7.2.2 Maintenance Procedures*

Maintenance procedures and frequency should follow those recommended by the manufacturer. In the absence of such recommendations, see Appendix G for suggested procedures.

*Basis:* NFPA 111, Annex A

## 8.0 GUIDANCE

### 8.1 Operations Guidance

#### *8.1.1 Maintenance Intervals*

Appendix A shows maintenance intervals for the SEPSS operations described in parts 6.1 and 7.1 of this document.

### 8.2 Maintenance Guidance

#### *8.2.1 Maintenance Intervals*

Appendix B shows intervals for the SEPSS maintenance described in parts 6.2 and 7.2 of this document.

#### *8.2.2 Expected Life*

Appendix C is information about the expected life of SEPSS components and guidance for their scheduled replacement.

# 9.0 REQUIRED DOCUMENTATION

**Table 9-1: Maintenance History Documentation Parameters**

| Parameter | NFPA 111 Level 1 | NFPA 111 Level 2 |
|---|---|---|
| **Maintenance Activities** | | |
| Maintenance Date | **Required** | **Required** |
| PM Activities Performed | **Required** | **Required** |
| Parts Replaced | **Required** | **Required** |
| Modifications Made | **Required** | **Required** |
| Post Maintenance Testing Performed | **Required** | **Required** |
| Identification of Maintenance Personnel | **Required** | **Required** |
| | | |
| Failure Dates | **Required** | **Required** |
| Failure Root Cause | **Required** | **Required** |
| Corrective Actions Taken | **Required** | **Required** |
| Parts Replaced | **Required** | **Required** |
| Post-Repair Testing Performed | **Required** | **Required** |
| Date Returned to Service | **Required** | **Required** |
| Identification of Servicing Personnel | **Required** | **Required** |
| Failure Dates | **Required** | **Required** |
| | | |
| Inspection Date | **Required** | **Required** |
| Inspection Performed | **Required** | **Required** |
| Tests Performed | **Required** | **Required** |
| SEPSS Condition | **Required** | **Required** |
| Meter Readings | **Required** | **Required** |
| Identification of Inspecting Personnel | **Required** | **Required** |

## 9.1 Reproducible Records

A reproducible record of inspection, tests, and repairs shall be maintained on the premises (See Appendix G.) The record shall include the following:

1. Completion of a log

2. Notification of any unsatisfactory condition and the corrective actions taken, including parts replaced
3. Identification of the servicing personnel
4. Documentation of a completed test of the Level 1 SEPSS immediately following any repair or battery replacement

*Basis:* Documentation of the parameters listed in Table 9-1 above satisfies the requirements of P 950, Section 3.5.15 which states, "A maintenance history and trending program is maintained to document data, provide historical information for maintenance planning, and support maintenance and performance trending of facility systems and components."

## 10.0 REFERENCES

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

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

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

**10.3** DOE Order 430.1B, Attachment 2 *Contractor Requirements Document* (paragraph 2, sections A through C)

**10.4** DOE Order 433.1B, *Maintenance Management Program for DOE Nuclear Facilities*

**10.5** DOE-STD-3003, *Backup Power Sources for DOE Facilities*

**10.6** DOE-STD-3009, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*

**10.7** IEEE Std. 446-1995, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*

**10.8** NETA MTS, 2007 *Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems,* InterNational Electrical Testing Association

**10.9** NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*

**10.10** NFPA 70, *National Electrical Code*

**10.11** NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*

**10.12** NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces*

**10.13** P 101-13, *Electrical Safety Program*

**10.14** P 101-3, *Lockout/Tagout for Hazardous Energy Control*

**10.15** P 315, *Conduct of Operations Manual*

**10.16** P 950, *Conduct of Maintenance*

**10.17** PD 311, *Requirements System and Hierarchy*

## 11.0 APPENDICES

Appendix A. SEPSS Operations Intervals
Appendix B. SEPSS Maintenance Intervals
Appendix C. Expected Life of SEPSS Components
Appendix D. Typical Static SEPSS
Appendix E. Typical Rotary SEPSS
Appendix F. Typical Redundant Static SEPSS
Appendix G. Suggested Maintenance Schedule for Solid-State Emergency Power Supply Systems

# APPENDIX A

# SEPSS OPERATIONS INTERVALS

Perform operations more frequently if recommended by the SEPSS manufacturer or indicated by equipment condition or operating environment. Corrective action should be taken for any item found to be deficient.

| | Static SEPSS | Rotary SEPSS | NFPA 111 Level 1 | NFPA 111 Level 2 | Acceptance Criteria |
|---|---|---|---|---|---|
| Perform post repair testing after any SEPSS repair or battery replacement. Perform all inspections specified under 6.1 & 7.1 then test the SEPSS under connected load for a minimum of 5 minutes or as specified for the SEPSS class, whichever is less. | **X** | **X** | **After any repair (Required)** | **After any repair (Required)** | No evidence of problems; meter readings within normal ranges. Supports load and voltages remain within manufacturer's specified range. |
| Check SEPSS externally. Check for evidence of problems by evaluating meter readings, sounds, smells, and detrimental environmental problems (heat, moisture, and chemicals). | **X** | **X** | Weekly | Weekly | No evidence of problems; meter readings within normal ranges. |
| Check all lamps using the "lamp test" feature. | **X** | **X** | Weekly | Weekly | All lamps operate properly. |
| Check all meters to ensure they are operating. | **X** | **X** | Weekly | Weekly | All meters operate properly. |
| Record SEPSS meter readings: voltmeter, ammeter, and frequency meter at input and output. | **X** | **X** | Weekly | Weekly | Meter readings within normal ranges. |
| Verify that the disturbance monitor is operable, if the SEPSS is so equipped. | **X** | **X** | Weekly | Weekly | Disturbance monitor is operational. |
| Check the appearance and cleanliness of all equipment, the room/area. | **X** | **X** | Weekly | Weekly | SEPSS is clean. SEPSS room/area is clean and not used for storage. |
| Inspect the HVAC equipment and measure the room/area temperature and humidity. | **X** | **X** | Weekly | Weekly | HVAC equipment operating. Temperature and humidity within limits specified by the SEPSS manufacturer. |
| Check all SEPSS equipment air intakes and exhausts, including filters. | **X** | **X** | Weekly | Weekly | Filters not clogged. Fans operational. |
| Contact SEPSS manufacturer for information on equipment upgrades and recommended revisions. | **X** | **X** | Bi-Annually | Bi-Annually | Action completed. |

# APPENDIX B

# SEPSS MAINTENANCE INTERVALS

Perform maintenance more frequently if recommended by the SEPSS manufacturer or indicated by equipment condition or operating environment. Corrective action should be taken for any item found to be deficient.

| | Static SEPSS | Rotary SEPSS | NFPA 111 Level 1 | NFPA 111 Level 2 | Acceptance Criteria |
|---|---|---|---|---|---|
| Check the SEPSS battery and associated charger/control equipment. (Refer to Criterion 511, *Stationary System Batteries* for additional requirements and recommendations.) | X | X | Monthly (Required) | Quarterly | Verify that they are in a clean and satisfactory condition and no exceptional environmental or other conditions exist that could damage or affect performance. |
| When applicable, check the SEPSS battery electrolyte levels and refill as necessary. Clean and re-grease battery terminals and intercell connectors as necessary. Clean cell tops. (Refer to Criterion 511, *Stationary System Batteries* for additional requirements and recommendations.) | X | X | Monthly (Required) | Quarterly | Electrolyte levels to battery manufacturer's specifications. No corrosion evident on battery terminals or intercell connections. |
| Check and record individual cell voltages where practical. (Refer to Criterion 511, *Stationary System Batteries* for additional requirements and recommendations.) | X | X | Monthly (Required) | Quarterly | Cell voltages within manufacturer's specified range. |
| Check and record the specific gravity of pilot cells where applicable. (Refer to Criterion 511, *Stationary System Batteries* for additional requirements and recommendations.) | X | X | Monthly (Required) | Quarterly | Specific gravity within manufacturer's specified range. |
| Note the condition of the plates and sediment of free-electrolyte, lead-acid batteries in transparent containers. (Refer to Criterion 511, *Stationary System Batteries* for additional requirements and recommendations.) | X | X | Monthly (Required) | Quarterly | Condition within manufacturer's specified range. |
| Perform a load test. For each battery set, record the SEPSS output voltage, the battery voltage, and the duration of the test at the beginning and end of the test. | X | X | Monthly (Required) | Quarterly | SEPSS supports the load and voltages remain within manufacturer's specified range. |
| Check that all SEPSS indicator lamps, meters, and controls are operating correctly. | X | X | Monthly (Required) | Quarterly | All operating properly. |

| | Static SEPSS | Rotary SEPSS | NFPA 111 Level 1 | NFPA 111 Level 2 | Acceptance Criteria |
|---|---|---|---|---|---|
| Check the SEPSS load value to ensure that it is within the SEPSS rating. | X | X | Monthly (Required) | Quarterly | Within manufacturer's specified range. |
| Measure SEPSS phase and neutral output currents during peak loading. Measurement should be made using a true RMS type ammeter. | X | | Monthly | Quarterly | Verify that the neutral conductor ampacity is not exceeded |
| Inspect all parts for evidence of overheating. | X | | Monthly | Quarterly | No evidence of overheating. |
| Inspect terminals for loose or broken connections, burned insulation, etc. | X | | Monthly | Quarterly | No loose or broken connections. |
| Check for liquid contamination (battery electrolyte, oil from capacitors, etc.) Inspect inverter for signs of leaking fluid from the wave-forming capacitors; check capacitors for swelling or discoloration. | X | | Monthly | Quarterly | No liquid contamination. |
| Clean the inside of all equipment enclosures and clean the components within. | X | | Monthly | Quarterly | Enclosure and components are clean. |
| Exercise each NFPA 111 Level 1 SEPSS under connected load for a minimum of 5 minutes or as specified for the SEPSS class, whichever is less. | X | X | Quarterly (Required) | Semi-Annually | SEPSS supports load and output voltage and frequency remain within manufacturer's specified range. |
| Inspect all parts for evidence of overheating. | | X | Quarterly | Semi-Annually | No evidence of overheating. |
| Inspect all parts for evidence of physical damage, including worn insulation and corrosion. | | X | Quarterly | Semi-Annually | No physical damage, worn insulation or corrosion. |
| Inspect terminals for loose or broken connections, burned insulation, etc. | | X | Quarterly | Semi-Annually | No loose or broken connections. |
| Check connections for tightness. | | X | Quarterly | Semi-Annually | Connections have proper torque. |
| Clean the inside of all equipment enclosures and clean the components within. | | X | Quarterly | Semi-Annually | Enclosure and components are clean. |
| Check all bearings and their lubrication. (IEEE 446) Refer to Criterion 510, AC Motors, for additional guidance on maintenance of rotating equipment. | | X | Quarterly | Semi-Annually | Bearings are not overheating or noisy and are properly lubricated. |
| Test alarm shutdown functions. | | X | Quarterly | Semi-Annually | Alarm shutdown functions performed as specified by the manufacturer. |

| | Static SEPSS | Rotary SEPSS | NFPA 111 Level 1 | NFPA 111 Level 2 | Acceptance Criteria |
|---|---|---|---|---|---|
| Check tightness of electrical connections and utilize infrared scanning under load or testing with a digital low-resistance ohmmeter. Clean and re-tighten as necessary. | X | X | Semi-Annually | Annually | No loose or corroded connections. |
| Check and adjust voltage output and frequency according to manufacturer's specifications. | X | | Semi-Annually | Annually | Output voltage as specified by the manufacturer. |
| Test alarm shutdown functions. | X | | Semi-Annually | Annually | Alarm shutdown functions performed as specified by the manufacturer. |
| Perform light-load test. | X | X | Annually | 18 Months | SEPSS output voltage and frequency remains within manufacturer's specified limits. Control switches and meters operate properly. |
| Perform synchronization test. | X | X | Annually | 18 Months | The rate of change of output frequency and the output voltage remain within manufacturer's specifications. |
| Perform AC input failure test | X | X | Annually | 18 Months | The DC source instantly sustains the critical loads. SEPSS output voltage and frequency remain within limits manufacturer has specified. |
| Perform AC input return test. | X | X | Annually | 18 Months | The rectifier instantly sustains the critical loads and recharges batteries (if used). SEPSS output voltage and frequency remain within limits manufacturer has specified. |
| Perform transfer test – (For SEPSS that use a Static Bypass Switch.) | X | X | Annually | 18 Months | Transients and transfer times remain within manufacturer's specified limits. |
| Perform rated full-load test. | X | X | Annually (Required) | 18 Months | SEPSS supports rated load for the full duration of its class. |
| Perform output-voltage balance test. | X | | Annually | 18 Months | The output phase-to-phase and phase-to-neutral voltages and angles remain within manufacturer's specified limits for full rated balanced and unbalanced loads. |

| | Static SEPSS | Rotary SEPSS | NFPA 111 Level 1 | NFPA 111 Level 2 | Acceptance Criteria |
|---|---|---|---|---|---|
| Perform harmonics-Components test. | X | | Annually | 18 Months | Harmonic content in the output voltage for rated linear and non-linear load conditions remain within manufacturer's specified limits for full rated balanced and unbalanced loads. |
| Check and test all circuit breakers. Refer to Criterion 504, Low Voltage Electrical Equipment, for additional guidance on maintenance of circuit breakers. | X | X | 18 Months | Bi-annually | All circuit breakers function within limits set by the manufacturer. |

# APPENDIX C
# EXPECTED LIFE OF SEPSS COMPONENTS

### Transformers, Inductors, DC Chokes

The design life of most magnetic components is 20 years of operation. Key factors are the temperature rating of the insulation used in the winding process and the temperature rise while in service. Some commutation inductors have exhibited deterioration after ten to fifteen years of service due to load variations and the constant cycling of the current through the inductor. Before failure, such inductors will start to vibrate and become very noisy. This condition will be obvious during preventive maintenance, and replacement can be scheduled. SEPSS manufacturers' experience indicates that with proper preventive maintenance, no definitive replacement interval of magnetic components is needed to preclude inadvertent SEPSS shutdown.

### Power Semiconductors

The power semiconductors used in typical SEPSS do not have a rated end of life in the normal mode of operation of the SEPSS. The only way to tell if a power semiconductor is about to fail is to test leakage current. If it is above the maximum rated value for the device being tested, then the device should be changed.

During the annual maintenance, power semiconductors should also be inspected for corrosion and for damage to the hermetic seal. If corrosion or seal damage is found, the device should be replaced. Otherwise, changing the power semiconductors in large SEPSS is not generally recommended.

### Electrolytic DC Capacitors

The expected life of electrolytic capacitors can be calculated as a function of manufacturer's rating and the expected operating temperature of the device. Based on such calculations, the expected average service life is 8 years for capacitors manufactured and purchased before 1988. Due to improvements in the capacitors manufactured and purchased after 1988, the rated service life was extended to 15 years. These service life ratings assume an average room ambient temperature of 30°C (86°F). At a 35°C ambient temperature the average rated service life for electrolytic capacitors is reduced to 11 years; at a 40°C ambient temperature the average rated service life is reduced to only 8 years.

### Oil-Filled AC Capacitors

Oil-filled capacitors have an operating life of 10 years. They should be changed at that time due to the internal breakdown of the soggy foils and possible loss of capacitance. All oil-filled capacitors should be inspected, and those within 6 months of their service life

should be changed out during the annual maintenance. Each oil-filled capacitor should be inspected during annual maintenance for deformation, which indicates that the capacitor needs replacing. Changing AC oil-filled capacitors based on service life is generally not part of most maintenance contracts, but can be included.

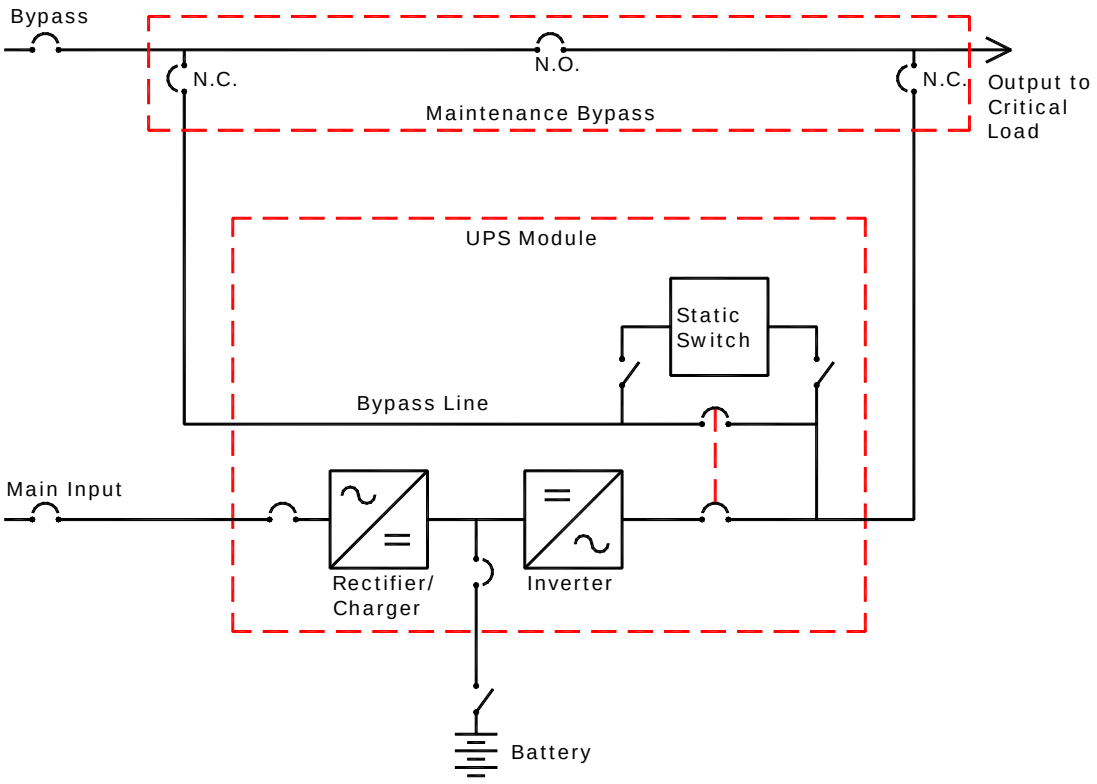
**Circuit Boards**

There is no rated service life for the electronic components used on circuit boards. Circuit boards with problems should be removed and returned to the manufacturer for repair and test. Before they are returned to service, they should have all outstanding revisions incorporated, and then should be system tested by the manufacturer. If a circuit board fails a second time for the same problem, it should be scrapped. All calibrations should be verified during annual maintenance to ensure that the circuit boards don't exhibit any signs of failure. If any weakness is seen, the circuit board should be replaced.

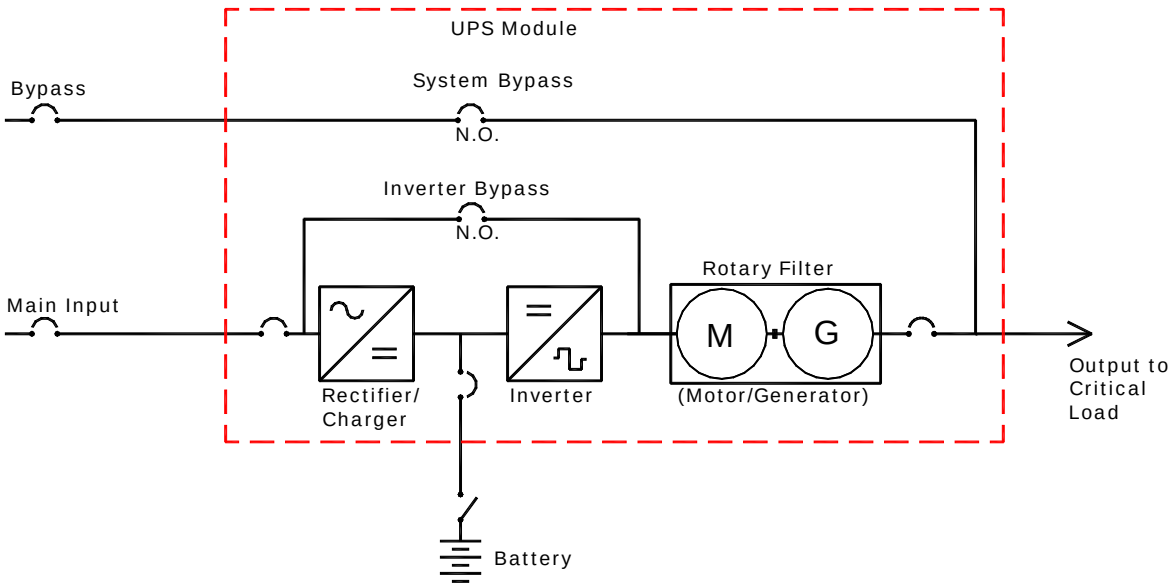
The most serious limitation to circuit board longevity is availability of replacement components for some boards. Certain parts are no longer available from their manufacturers. Most SEPSS manufacturers attempt to maintain stock on key components, but it's difficult to foresee all contingencies. This parts-availability issue affects all vendors of both static and rotary SEPSS products.

The information in this Appendix is based on a White Paper by Liebert entitled "Longevity of Key Components in Uninterruptible Power Systems".

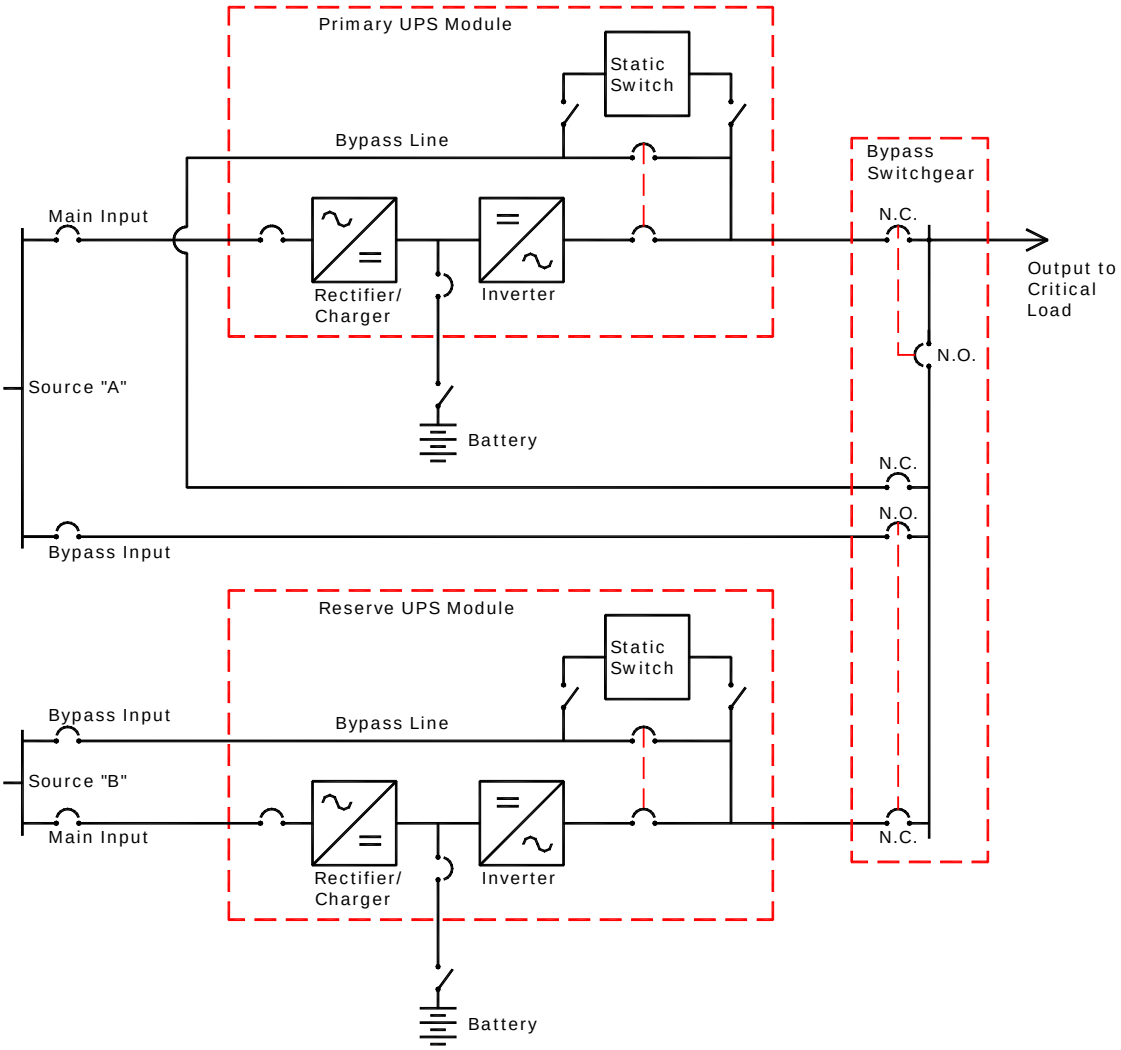
# APPENDIX D
# TYPICAL STATIC SEPSS



# APPENDIX E
# TYPICAL ROTARY SEPSS



# APPENDIX F
# TYPICAL REDUNDANT SEPSS



# APPENDIX G

# SUGGESTED MAINTENANCE SCHEDULE FOR SOLID-STATE EMERGENCY POWER SUPPLY SYSTEMS

| Item Component (as Applicable) | Procedure | | | | | Frequency |
|---|---|---|---|---|---|---|
| | Visual Inspection | Check | Change | Clean | Test | |
| Battery | | | | | | |
| Float voltage | | X | | | | Monthly |
| Cable connections | | X | | | | Semiannually |
| Terminals | | | | X | | Quarterly |
| Electrolyte gravity | | | | | X | Quarterly |
| Electrolyte level | X | | | | | Monthly |
| Replace cell or battery | | | X | | | See manufacturer's instructions |
| ECE | | | | | | |
| Power supply voltage | | X | | | | Monthly |
| Terminals | | X | | | | Semiannually |
| Panel meters | X | | | | | Monthly |
| Panel lamps | X | | | | | Monthly |
| Circuit breakers, fuses | X | X | X | X | | Every 2 Years |
| Battery charger | | | | | | |
| Output terminal volts | | X | | | | Monthly |
| Fuses | X | X | X | X | | Every 2 Years |
| Charge current | | X | | | X | Quarterly |
| Equalize voltage | | X | | | | Quarterly |
| Panel meters | X | | | | | Monthly |
| Panel lamps | X | | | | | Monthly |
| Load | | | | | | |
| Load current | | X | | | | Quarterly |
| Panel meters | X | | | | | Monthly |
| Transfer switch | | | | | | |
| Contacts | X | | | | | Annually |
| Test switch | | | | | X | Semiannually |
| Fuel cell | | | | | | |
| Check fuel supply (pressure/quantity) | X | | | | | Quarterly |
| Start up system | X | | | | | Quarterly |
| Exercise load until system heats up | | | | | X | Quarterly |
| Fuel supply piping | X | | | | | Annually |
| Exhaust piping | X | | | | | Annually |
| Air supply piping | X | | | | | Annually |
| Cooling system | X | | | | | Annually |
| Connectors | | | | X | | Annually |
| Fuel system pressure/leakage | | | | | X | Annually |
| Full load test | | | | | | Annually |
| Calibrate $H_2$ detector | | X | | | X | Annually |

(Based on Table A.8.3.2, page 17, NFPA 111, Annex A.)