NUCLEAR TRAINING

NUCLEAR OPERATIONS

COPY NO.______________

GENERAL SYSTEMS

GS-3

DC POWER

REVISION 14

Recommended ______________ Original Signed by Hitt A. Crider ______________ Date __02/20/08____________

Approved ______________ Original Signed by Rusty Quick ______________ Date __02/20/08____________

Supervisor, Development
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OBJECTIVES

TERMINAL OBJECTIVE: The student shall be able to describe the DC Power System as it applies to the operation of the V.C. Summer Station for his job category.

ENABLING OBJECTIVES: The student shall be able to:

GS-3-01 STATE the function or purpose of the DC power system. X X X X

GS-3-02 DRAW and LABEL a one-line diagram of the DC power system, including the switchyard, showing the following major components. X X X X
1. Battery charger power sources
   (switch-gear)
2. Battery chargers
3. Switchyard batteries and battery buses automatic power transfer unit.

GS-3-03 IDENTIFY the following flowpaths through the DC power system: X X X X
1. DC power system electrical flowpath
2. DC power battery charger power supplies
3. DC power battery loads.

GS-3-04 DESCRIBE the DC power system interfaces with the following systems and/or subsystems: X X X X
1. Engineered safety features system
2. Battery charger and battery.
STATE the purpose of the following components of the DC power system:

1. DC power battery chargers
2. DC power batteries
3. Switchyard automatic power transfer unit.

DESCRIBE the normal operation of the following DC power system components. INCLUDE component types and applicable setpoints.

1. DC power battery chargers
2. DC power batteries
3. Switchyard automatic power transfer unit.

DESCRIBE the construction of the following components:

1. DC power battery
2. DC power battery charger
3. Switchyard automatic power transfer unit.

DESCRIBE the normal operation of the following sub-systems of the DC power system:

1. Switchyard DC operation
2. Precautions associated with DC power electrical operations.
GS-3-09  **STATE** the plant location for the following components of the DC power system:

1. DC power batteries
2. DC power battery chargers
3. DC power DPNs
4. Switchyard automatic power transfer unit.

GS-3-10  **STATE** whether the following switches and controls for the DC power system are on the MCB or on local panels. For those on local panels, GIVE the name and location of the panel.

1. Battery charger AC input breaker
2. Battery charger DC output breaker
3. Battery charger AC output breaker
4. Battery charger DC input breaker
5. Battery charger selector switch (auto / float / equalize)
6. DC power DPN circuit breakers
7. Switchyard automatic power transfer unit.
DESCRIBE the component operation associated with each switch position for the following switches/controls:

1. Battery charger AC input breaker
2. Battery charger DC output breaker
3. Battery charger AC output breaker
4. Battery charger DC input breaker
5. Battery charger selector switch (auto/float/equalize)
6. Switchyard automatic power transfer unit.

DESCRIBE the normal operation of the following control systems. INCLUDE function, instrumentation and setpoints.

1. Battery charger float charge
2. Battery charger equalize charge.

DESCRIBE the normal operation of the DC power system including:

1. DC power normal battery charger voltage,
2. DC power normal battery charger amperage
3. Lead acid storage battery electrochemical operation.

IDENTIFY power supplies for the following DC power system components:

1. DC power battery charger
2. DC power batteries
3. DC power DPNs.
**GS-3-15** **DESCRIBE** the following DC power system interlocks. **SPECIFY** purpose and setpoints.

1. DC power switchyard automatic transfer unit normal and standby contact interlock
2. 120 VDC breaker (DPN) mechanical interlocks
3. Swing battery charger power supply mechanical interlocks.

**GS-3-16** **STATE** whether the following indicators for the DC power system are on the MCB or on local panels. For those on local panels, **GIVE** the name and location of the panel.

1. DC power battery charger amperage
2. DC power battery charger voltage
3. DC power battery bus voltage
4. DC power battery bus amperage
5. Switchyard DC power indicator.

**GS-3-17** **STATE** the reason for the following indicators available for the DC power system:

1. DC power battery charger amperage
2. DC power battery charger voltage
3. DC power battery bus voltage
4. DC power battery bus amperage
5. Switchyard DC power indicator.

**GS-3-18** **STATE** the Tech Spec limitations for the following items:

1. DC power safeguards battery operability
2. DC power battery charger operability.
GS-3-19 **INTERPRET** the applicability of the following Tech Specs to the DC power system including the surveillance requirements and bases.

1. Minimum sources operable: 3.8.2.1, 3.8.2.2 and 2) 3.8.3.1, 3.8.3.2.

GS-3-20 **EXPLAIN** the effect of the following failures of the DC power system:

1. Loss of DC power due to grounds
2. Loss of DC power due to exhaustion of safeguards batteries
3. Battery explosion hazards
4. Mispositioned DC power system breakers and switches.

GS-3-21 **DISCUSS**, in detail, all the recommendations of SOERs 81-15 and SOER 83-5 as they pertain to operator training.

GS-3-22 **DESCRIBE** how SOERs 81-15 and 83-5 applies to your job (the cause) and/or its significance to plant operations (the effect).

GS-3-23 **DETERMINE** which of the seven Human Performance tools could have been used to prevent or mitigate the events of SOERs 81-15 and 83-5.
INTRODUCTION

The DC Power System provides a highly reliable source of electrical power for the station’s safety-related and nonsafety-related instrumentation, control, and critical loads, both AC and DC. The system is highly reliable because it uses storage batteries as temporary power sources. The storage batteries are maintained in a fully charged condition and are used as emergency sources of power to the DC-AC inverters and other critical DC loads. These power sources are used when normal AC power is lost.

The function of the DC Power System is to provide DC power to three specific areas:

- Class 1E DC loads, control of Class 1E systems, and emergency lighting
- Nonsafety-related critical loads, controls, instrumentation and emergency lighting
- Switchyard circuit breaker control and protection relays

The DC Distribution system is a Probability Risk Assessment (PRA) "Risk Important System". It currently (as of 08/02/04) ranks #10 on the list of system importance. This means that any work or equipment problems on this system should be thoroughly evaluated for possible increased risk to plant safety and reliability.

GENERAL DESCRIPTION

The DC Power System consists of three 125 VDC electrical subsystems. These subsystems are the Class 1E subsystem, the non-Class 1E subsystem, and the Virgil C. Summer switchyard subsystem. The Class 1E 125 VDC subsystem consists of two independent trains of DC networks. Each network consists of redundant batteries, battery chargers, distribution circuits and panels, and DC loads which include the
DC-to-AC inverters. The major load on this subsystem is the vital instrumentation and control 120 VAC safeguards power subsystem via the DC-to-AC inverters.

The non-Class 1E 125 VDC subsystem consists of one electrical distribution network. The network consists of a battery, battery chargers, distribution circuits and panels, and DC loads which include DC-to-AC inverters. Its major loads consist of the plant’s computer, fire and security systems, and miscellaneous balance of plant nonsafety-related instrumentation and control loads. These loads are all powered via the DC-to-AC inverters.

The switchyard 125 VDC subsystem is similar to the non-Class 1E DC power subsystem. It also consists of a battery, battery chargers, distribution circuits and power panels, and DC loads. However, it does not supply power to any 120 VAC loads since it has no DC-to-AC inverters in its distribution circuit. Its major load consists of relay panels for control and protection of switchyard equipment.

**DETAILED DESCRIPTION**

**Class 1E 125 VDC Power Subsystem** (Figure GS3.1)

The safety-related Class 1E 125 VDC power subsystem is designed to provide physical separation, electrical isolation, redundancy, and independence as required by General Design Criteria 17 of 10 CFR 50, Appendix A. These design requirements ensure that any single failure does not prevent the Reactor Protection and Engineered Safety Feature systems from performing their intended safety functions.

The Class 1E 125 VDC power subsystem consists of two separate 125 VDC main distribution panels. These panels are DPN-1HA and DPN-1HB for the train A and the train B networks, respectively. They are both located on the 412’ level of the Intermediate Building. Each main panel is supplied DC power through a battery charger (XBC-1A and XBC-1B) and is backed up by a 60 cell, lead-acid storage battery with a
nominal float voltage of 2.20 to 2.25 VDC per cell. The battery chargers are powered by a 480 VAC safeguards power motor control center (MCC). MCC-1DA2X feeds DPN-1HA via battery charger XBC-1A for train A and MCC-1DB2X feeds DPN-1HB via battery charger XBC-1B. A third battery charger, XBC-1A-1B, is provided as a standby, or "swing," charger. It can supply DC power to either DPN-1HA or DPN-1HB, but not concurrently. MCC-1DA2Y or MCC-1DB2Y feeds XBC-1A-1B.

The three solid-state battery chargers each have sufficient capacity to charge a battery from design minimum voltage to the fully charged state within 12 hours. This 12 hour charging period can be performed while supplying the maximum design steady-state DC load under any plant operating condition. The battery chargers have input and output circuit breakers for isolation. The battery chargers are also designed to prevent the 480 VAC power supply circuit from becoming a load in the event of a loss of AC power by means of blocking diodes in the circuit. The battery chargers are rated at 300 amps at 132 VDC and are located in separate rooms in the Intermediate Building on the 412' level. The standby battery charger (XBC-1A-1B) backs up either of the normal power supply battery chargers. It is provided with a set of two transfer switches consisting of mechanically and Kirk Key interlocked circuit breakers on the AC input and the DC output located in transfer switch XET 4003-ED. This interlock prevents cross connecting both trains of power. 'A' train AC cannot be utilized to supply 'B' train DC via the 1A1B battery charging normally.

The "A" train ac breaker - "B" train dc breaker, and the "B" train ac breaker - "A" train dc breaker have Kirk Key interlocks so that only one breaker of each pair can be on at one time. The "A" train - "B" train ac breakers, and the "A" train - "B" train dc breakers have mechanical walking beam interlock so that only one breaker of each pair can be on at one time. Mechanical walking beam interlocks typically are mounted above the operating handles for a particular breaker scheme (two circuit breakers). The walking beam is a pivoting bar that prevents the closing of a particular breaker when another breaker is closed. This mechanical feature for the "swing" charger is located internally within the cabinet and can not be seen without removing the cover over the walking beam.
beam assembly. The key that fits 'A' train AC breaker also fits 'B' train DC breaker with the other key fitting the other respective AC/DC breakers.

The two safety-related 125 VDC storage batteries, XBA-1A and XBA-1B, are 60-cell batteries with a sulfuric acid and water electrolyte. This type of battery is commonly referred to as a lead-acid storage battery. Each battery is located in a separate room in the Intermediate Building on the 412' level. Each battery room has its own separate ventilation supply and exhaust fans to preclude hydrogen buildup. Dampers isolate the battery room to protect the battery from low temperatures (< 70°F) and will isolate to provide train separation during a safety injection signal ("A" side "B" damper will close; "B" side "A" damper will close). The batteries are mounted on protected, corrosion resistant steel racks for security and to facilitate maintenance. The batteries and their racks are designed to remain operational during a safe shutdown earthquake (SSE). The storage batteries of the two trains cannot be interconnected and do not have a common failure mode. In the event of a loss of AC power or a failure of a battery charger, the batteries supply power to the safety-related DC loads. Any momentary load surges in excess of the battery charger's capacity are absorbed by the batteries. The batteries are maintained fully charged and have sufficient capacity to operate all loads for a minimum of 4 hours after a loss of AC power. Two types of battery discharge tests are performed periodically to verify loading requirements. One test involves a constant current discharge at 367.5 amps nominal (temperature correction applied) until battery voltage reaches 108 volts. Four hours corresponds to 100% battery capacity. The other test is a service test where the test current varies to envelope the worst-case accident loading on the battery for 4 hours. This test proves that the battery can supply the design loading. SOP-311, Enclosure A, lists the battery capacity ratings.

The main DC loads are:

- Instrumentation inverters (backup source)
- ESF control power
• DG control power and field flash
• Circuit breaker closing and tripping power
• Control room emergency lighting
• Miscellaneous controls and alarms

The batteries and battery charger outputs are supplied to main distribution panels DPN-1HA and DPN-1HB via air-break circuit breakers. These supply circuit breakers have auxiliary contacts that actuate the following annunciators on the MCB to alert the operator of their position:

• "PNL 1HA (1HB) INCM BKR FR BATT 1A (1B) OPEN"
• "PNL 1HA (1HB) INCM BKR FR CHG 1A (1B) OPEN"
• "PNL 1HA (1HB) INCM BKR FR CHG 1A-1B CLSD"

DPN-1HA and DPN-1HB distribute power to DC loads, DC-to-AC inverters, and smaller DC distribution power panels. Panel DPN-1HA feeds DC panels DPN-1HA1, DPN-1HA2, and DPN-1HA3. These three panels are located in the Intermediate, Control, and Service Water Buildings, respectively. Panel DPN-1HB feeds DC panels DPN-1HB1, DPN-1HB2, and DPN-1HB3, also located in the Intermediate, Control, and Service Water Buildings, respectively. Refer to SOP-311, Attachment IA and IB (Train A(B) Vital and Safeguards 125 VDC Electrical Lineup) for a list of vital loads. Notice that DPN-1HB3 supplies DC control power for the Reactor Coolant Pump breaker trip coils through isolation fuse panel XPN-5254. This provides a more reliable control power source for the RCP breaker trip coils (previously supplied by Non-Class 1E 125 VDC). There are no provisions for operating the 125 VDC safety-related equipment from the control room. Instrumentation on the MCB displays the 125 VDC safety-related battery voltage and the battery charger’s output current. A single zero-center-scale ammeter provides output indication for charger XBC-1A-1B.
Non-Class 1E 125 VDC Power Subsystem (Figure GS3.1)

The nonsafety-related, non-Class 1E 125 VDC power subsystem consists of a main distribution power panel or bus, one 125 VDC battery, and primary and backup battery chargers. Main distribution power panel DPN-1HX is supplied DC power from battery chargers XBC-1X and XBC-1X-2X. Storage battery XBA-1X acts as a backup source of DC power during loss of AC power to the battery chargers. Power to the battery chargers is supplied by 480 VAC safeguards power motor control centers. MCC-1DA2Y feeds battery charger XBC-1X, and MCC 1DB2X feeds battery charger XBC-1X-2X.

The solid-state battery chargers are similar to the Class 1E battery chargers but are rated at 400 amps through the full voltage range. Each charger is adequately sized to carry the maximum steady-state DC load while also recharging the battery within a 12 hour period. Both chargers have undervoltage and current-limiting protection identical to that of Class 1E battery chargers.

The 125 VDC battery (XBA-1X) consists of 60 lead-acid cells. It is located in the Intermediate Building on the 412’ level. The battery has adequate capacity to power its DC loads for a 2 hour period following loss of AC power.

The output of the battery and the battery chargers is directed to main distribution panel DPN-1HX via air-break circuit breakers. These circuit breakers have auxiliary contacts that actuate control room annunciators on the MCB. These annunciators alert the operator to the status of the battery and the battery chargers outputs:

- "PNL 1HX INCM BKR FR BATT 1X OPEN"
- "PNL 1HX INCM BKR FR CHG 1X OPEN"
- "PNL 1HX INCM BKR FR CHG 1X-2X CLSD"
Main Distribution Panel DPN-1HX directs power to various other smaller DC distribution panels and DC-to-AC inverters XIT-5905 and -5906. The panels are DPN-1HX1, DPN-1HX2, DPN-1HX3, and DPN-1S. They are located in the Control Building, Auxiliary Building, Turbine Building and Switchyard Relay House, respectively. Panel DPN-1S is a DC distribution panel in the switchyard DC power subsystem. DPN-1HX is the emergency or backup power to the switchyard DC power subsystem, as discussed later. In addition to the above DC power panels, two other small DC distribution panels are fed from a connection just upstream of the 1X battery’s output circuit breaker. These panels are DPN-1X and DPN-2X. Loads from these two panels are not isolated from the battery when the battery output breaker is open. However, there is a safety disconnect switch for panel DPN-1X. Major loads on panels DPN-1X and DPN-2X are the plant security system’s DC-to-AC inverters and the emergency oil pumps for the main turbine and feedwater pump turbines, respectively. Refer to SOP-311, Attachment II (Balance of Plant 125 VDC Electrical Lineup), for a listing of all loads on the non-Class 1E DC power subsystem.

There are no remote control capabilities in the control room for non-Class 1E DC power equipment and circuit breakers. All circuit breaker and battery charger operations are performed locally at their respective areas. Battery chargers XBC-1X and XBC-1X-2X current outputs and battery DC voltage are indicated on the MCB.

**Ground Detection**

The battery distribution system is usually ungrounded to enhance reliability. Either polarity, but not both, can become grounded without causing failure of the distribution system. Ground detection devices should signal an alarm if either polarity becomes grounded, thus permitting time to isolate and repair a fault before the other polarity develops a ground.
Grounding of the distribution system may not necessarily occur through a direct metallic contact. In many cases, it may be grounded by water in a limit switch, dirty cell tops, or breakdown of the insulation of relays, solenoid, or the like. In any case, the grounding of the dc system can indicate the failure of a component within the system.

The 125 VDC system (class 1E and non-class 1E) is designed to operate in a "floating" condition that is with neither the positive nor the negative phase connected to ground. An installed ground detector checks both phases for any phase-to-ground current and generates a computer alarm and a main control board annunciator if a ground is indicated. The values of resistance to ground that cause alarms vary, because the magnitude of both the positive-ground resistance and the negative-ground resistance affect the current in the detector ammeter. An alarm can occur for resistance as high as 30,000 ohms on both legs. A local ammeter on the 412' IB indicates current to ground (alarm is generated if greater than 5 mA for 5 seconds or 2.5 mA for 450 seconds). The alarm setpoints and operator actions are discussed on Attachment II.

Locating DC grounds can be difficult. Individual component breakers are opened, and the ground rechecked; when grounds return to normal, the ground has been isolated. Even this method is difficult to perform at power, due to making components inoperable and creating unacceptable conditions for those components (containment isolation valves, etc.) that will fail open or closed when DC control power is removed. One example of the unexpected results that can arise while cycling control power is that if control power to 1DA is interrupted, the bus undervoltage (27-1DA) relays drop out, causing a diesel start. However, this method will locate a single ground. If the DC system is permitted to deteriorate to the point where multiple grounds exist, isolating any single load won't clear the ground; a plant shutdown to strip the DC bus and reenergize one load at a time (checking grounds after each breaker is closed) may be required. Electrical maintenance personnel will assist in the investigation of DC grounds.
Clearly, maintenance of the Class 1E DC system in a clean, ungrounded condition is vital to plant safety and reliability. Small problems such as dirty batteries, loose cables/pulled flexible metal jackets on solenoid valves, etc., can add up to cause the difficult transients discussed under operations.

**Switchyard 125 VDC Power Subsystem** (Figure GS3.2)

The switchyard 125 VDC power subsystem for the 230 kV substation, or switchyard, consists of a 125 V battery, two battery chargers, and three DC distribution power panels. This equipment is located in the relay house in the 230 kV switchyard. Main distribution panel DPN-1S is powered from battery chargers XBC-1S and XBC-1S-2S. The two battery chargers are powered from the switchyard 480 VAC service power main distribution panel APN-1M via a 480 to 240 V step-down transformer and AC power panel APN-1HB. Panel APN-1M is powered from 480 V service power switchgear units 1A1 or 1B1 via an automatic power transfer unit (XET-1M). Storage battery XBA-1S serves as a backup power supply to DC distribution panel DPN-1S upon a loss of AC power. Additionally, an emergency DC feed from DPN-1HX provides DC power should AC power be lost while the battery (XBA-1S) is out of service. Fuse holders in the feeder line from panel DPN-1HX are located in panel DPN-1S and have their fuses removed for normal operation.

The 480 VAC automatic transfer unit (XET-1M) is a double-throw switch with normal and standby contacts that are mechanically and electrically interlocked to prevent simultaneous closing. It has a solenoid-operated mechanism and is mechanically locked in either position. Transfer to the standby source (1B1) occurs when any phase of the normal source (1A1) drops below 70 percent of rated voltage. It automatically returns to normal when all three phases of AC power from the normal supply are restored to 90 percent of rated voltage (normal-seeking).
The two battery chargers (XBC-1S and XBC-1S-2S) are located in the switchyard relay	house next to the battery room. They have electronic AC-to-DC power conversion
circuits and are designed for load sharing.

Each charger includes a DC voltmeter, an ammeter, and circuit breakers in the input
and output circuits. They also have an AUTO/FLOAT/EQUALIZE selector switch for
operation in either of these three modes. (Refer to the section on the battery chargers
for a description of the selector switch positions.) The battery chargers are voltage
regulated and current limited in both the FLOAT and EQUALIZE modes. The battery
chargers are intended to be parallel operated. However, one charger is capable of
supplying the entire DC load in case one fails.

The 125 VDC switchyard battery (XBA-1S) consists of 60 lead-acid cells. Upon a loss
of charging current, the battery continues to carry the connected steady-state DC load
for a period of 4 hours including 10 switchyard breaker trips and 1 switchyard breaker
closing. The battery is rated at 350 ampere-hours (for a 4 hour period).

Distribution panel DPN-1S serves as a junction point for the switchyard battery, battery
chargers, and emergency DC feed from DPN-1HX. It also serves as a distribution panel
for its DC loads. These DC loads include the 125 VDC primary and backup DC
distribution panels. The primary panel is DPN-1SP, and the backup panel is DPN-1SB.
These panels provide primary and backup power to the switchyard circuit breaker
control and relay panels.

System Components

Lead-Acid Storage Battery

The lead-acid battery is an electrochemical device for storing chemical energy until it is
released as electrical energy. Active materials within the battery react chemically to
produce a flow of direct current whenever current-consuming devices are connected to
the battery terminal posts. This current is produced by chemical reaction between the active material of the plates (lead electrodes) and the electrolyte (sulfuric acid). A small amount of calcium is used to stiffen the lead plates, leading to the alternate name "lead-calcium battery" (antimony was previous used).

A lead-acid battery consists of a number of cells connected together; the number needed depending upon the voltage desired. Each cell produces approximately 2.15 volts. The most limiting (weakest) cell is designated the pilot cell and is checked frequently for voltage and electrolyte specific gravity.

Vent plugs permit the escape of gases that form within the cells, while preventing leakage or loss of the electrolyte. These openings are also used to determine the level and specific gravity of the electrolyte.

In its charged condition, the active materials in the lead-acid battery are lead peroxide (used as the positive plate) and sponge lead (used as the negative plate) (Figure GS3.4). The electrolyte is a mixture of sulfuric acid and water. The strength (acidity) of the electrolyte is measured in terms of its specific gravity. Specific gravity is the ratio of the weight of a given volume of electrolyte to an equal volume of pure water. Concentrated sulfuric acid has a specific gravity of about 1.830; pure water has a specific gravity of 1.000. The acid and water are mixed proportionately to give the specific gravity desired. For example, an electrolyte with a specific gravity of 1.210 requires roughly one part of concentrated acid to four parts of water. This is the specific gravity of a fully charged cell.

In a fully charged battery the positive plates are pure lead peroxide, and the negative plates are pure lead. Also, in a fully charged battery, all the acid is in the electrolyte and the specific gravity is at its maximum value. The active materials of both the positive and negative plates are porous and have absorption qualities similar to a sponge. The pores are, therefore, filled with the battery solution (electrolyte) in which they are immersed.
When sulfuric acid (H₂SO₄) is diluted in water, the following reaction occurs:

\[ H₂SO₄ + 2H₂O \rightarrow 2H₃O + SO₄^{2-} + \text{heat} \]

Acid should always be added to water (to limit the temperature produced). Highly concentrated acid (1.830 specific gravity) must not be added to the battery, otherwise overheating can occur.

The basic chemical reaction occurring at the negative plate when the cell discharges is the loss of electrons by lead (oxidation):

\[ Pb + SO₄^{2-} \rightarrow PbSO₄ + 2e⁻\]

At the positive plate, lead peroxide gains electrons and passes into solution as Pb²⁺ ions (reduction). The Pb²⁺ ions combine with SO₄⁻² ions, again forming PbSO₄⁺.

\[ PbO₂ + 4H₂O + SO₄^{2-} + 2 + 2e⁻ \rightarrow PbSO₄ + 6H₂O \]

These equations show that an excess of electrons is produced at the negative plate and that electrons are consumed at the positive plate. Thus, a flow of electrons (current) occurs when an external path is provided between the negative and positive plates. The equations also show that as the cell discharges, a coating of insoluble lead sulfate (PbSO₄) builds up on both the positive and negative plates. The PbSO₄ causes an expansion of the materials into the voids, or pores, of the plates and results in a gradual clogging. If the discharges are prolonged, excessive expansion may occur. Expansion can cause the plates to swell, creating mechanical stresses which reduce battery life.
Another effect during discharge is the consumption of $\text{SO}_4^{2-}$, causing the acid concentration of the electrolyte to decrease. This results in a decrease in the specific gravity of the electrolyte. When so much of the active material has been converted into lead sulfate that the cell can no longer produce sufficient current, the cell is discharged.

The amount of sulfuric acid combining with the plates at any time during discharge is in direct proportion to the amount of discharge. Therefore, the specific gravity of the electrolyte is a guide in determining the state of discharge of the lead-acid cell. The specific gravity of the electrolyte in battery cells is routinely measured to determine the state of charge of the battery. A specific gravity of 1.200 is considered fully charged.

The above two reactions are reversed during the charging cycles. Figure GS3.5 shows the chemical action of the battery during the discharge and charging processes.

**Battery Charger**

The battery chargers for all three 125 VDC power subsystems are similar in construction and operation (Figure GS3.6). The battery chargers consist of thyristor-controlled rectifiers with solid-state output voltage regulators and smoothing capacitors. The battery chargers use power rectifiers to convert the three phase AC input to a DC output. This generates a significant amount of heat from the rectifiers which is removed by internal cooling fans. Each battery charger features automatic float and equalize cycling to ensure optimum battery performance. Each of the battery chargers has local meter indication of output current and voltage. Each charger also has indicating lamps to show if input power is available, if output capacitors are fully charged, if output is grounded, and if the charger is in an equalize charging mode. Input and output circuit breakers and a FLOAT/EQUALIZE selector switch are also located on the charger’s panel. The battery charger should not be connected to the bus until the output capacitors are fully charged.
**Float Voltage** — The float voltage is the voltage required to maintain the battery in a fully charged condition, compensating for the internal losses in the battery. To minimize gassing, the value of the charge voltage should be 2.17 to 2.25 V/cell for lead-calcium. The float voltage should be adjustable over a minimum range of 2.10 to 2.25 V/cell.

**Recharging And Equalizing Voltage** — The recharging and equalizing voltage is that required to recharge the battery to 95% of full charge within a prescribed period of time after a discharge. The charging voltage is normally 2.33 V/cell for lead-calcium cells. It should be adjustable over a minimum range of 2.25 to 2.35 V/cell. This voltage is also used when equalizing the cells of the battery. Because not all cells charge at the same rate, the voltages of the individual cells can be higher or lower than the average voltage even though the battery terminal voltage is normal. A longer charging period at an elevated voltage helps to ensure that each cell has a voltage equal to that of the other cells and that each carries an equal share of the load. The only difference between recharging and equalizing the battery is the length of time the voltage is applied. Each battery manufacturer has specific instructions regarding equalizing voltage and time to satisfy the design. The data should be used during equalizing.

When equalizing, care must be taken to ensure that the higher voltage does not exceed the maximum acceptable limit for the connected load devices. A single-cell charger, for equalizing of a disconnected cell, may also be done. The single cell charger is normally used to recharge a single cell that has a low specific gravity.

An equalizing charge should be initiated when performing the following STPs every 60 months:

- STP-501.003 - Battery Service Test
- STP-501.004 - Battery Capacity Test
**Voltage Sensors** — Charger failure can cause output voltage to change abnormally, damaging the battery and various loads connected to the dc bus. Overvoltage (140 VDC) and undervoltage (126 VDC) sensors detect these conditions.

**Input AC Breaker** — The input breaker is used to clear faults in the ac side of the charger or in the cables connecting the breaker and the charger. The trip setting should be at about 125% of the full-load input current. Faults on the dc side of the charger are not reflected in the ac side. The breaker's interrupting capability should be equal to or greater than the fault current available at the input terminals of the charger.

**Output DC Breaker** — The output breaker is used to disconnect the charger and the clear faults in the dc side of the charger and the connecting cables between the charger and the breaker. Its interrupting capability should be greater than the fault current that could be delivered from the battery at the charger output terminals.

The trip setting should be at about 125% of the charger's full-load current. A higher setting (150%) may be selected if it is anticipated that the charger output will be greater than 125%. Chargers are current limiting at 125% and below.

**Output Filtering** — Three filter capacitor panels, one connected across the dc output of each Class 1E battery charger, are provided to support Class 1E ED System operation when system power is supplied from the battery charger with the associated train of battery disconnected. Nuclear Operations was not able to properly perform maintenance and calibration of the Class 1E ED System battery chargers without the addition of filter capacitors. When not connected to the battery, ripples created as much as 160 volts peak on the dc bus. Prior to the addition of filter capacitor panels, the excessive ripple had seriously damaged the plant annunciators when the battery was isolated from the bus for maintenance.
Non-Class 1E Battery Charger XBC-0004-ED — Non-Class 1E single cell battery charger XBC-0004-ED is not required to perform any NSR function. However, it is used to supply an equalizing charge to a cell whose voltage has dropped below the minimum acceptable voltage specified in Tech. Specs. Repetitive use of the single cell charger on a cell must be limited by procedure to prevent masking of a bad cell.

The single cell charger is used to restore a limited number of cells to a full charge without having to apply an equalizing voltage charge to the entire battery and subsequently to the connected dc system loads.

The single cell charger is located in the 1A-1B Battery Charger Room (IB-412) with disconnects to connect it to one of the Battery Rooms. With one of the disconnects closed, a set of Battery Charger cables are used to recharge the low Battery cell. The cables are long enough to reach anywhere in the Battery Room.

A note on the single cell charger cabinet in each Battery Room specifies that the charger must be connected across at least 3 cells but no more than 17 cells. If you are going to perform an equalizing charge on one cell then it will have to be at least 3.

DC System Maintenance

DC systems, particularly batteries, are special maintenance items. Normally, the entire system, after correct installation, will function for long periods with a minimum of routine maintenance. Operations can be further enhanced and the time between routine checks increased with a maintenance program involving personnel who are thoroughly familiar with the needs and operation of the individual components. Qualified personnel with an interest in the system and knowledge of the details required to make it function are the most important ingredients of a successful program.
Battery — Charging the battery and adding makeup water are part of battery maintenance. The maintenance program also includes visual inspections and measurements of important parameters such as intercell resistance and electrolyte specific gravity. Good record keeping adds to the effectiveness of the maintenance program.

To keep a check on battery condition, a pilot cell, is chosen. The pilot cell has the lowest specific gravity of all cells. One pilot cell is common for 60-cell batteries; two pilot cells would be appropriate for larger batteries. The values of voltage, specific gravity, and water consumption should be compared on a quarterly basis to ensure that all cells meet Tech Spec requirements and that the pilot cell is representative (lowest specific gravity) of battery capacity. Pilot cell parameters should only be checked while the battery is on a float charge. Taking pilot cell voltages during an equalizing charge can result in a cell passing the voltage limits in the tech spec table that may not pass if the voltage is taking while on a float charge.

Review of the pilot cell values and visual observations can provide valuable information about battery trends for the maintenance program. The staff can use these trends as a guide to:

- Modify charger settings
- Establish water consumption criteria for scheduling level adjustments
- Flag the need for intercell resistance checks
- Indications of a fully discharged battery

Remember that the battery and associated equipment must function when all else fails. The quality of a maintenance program will be evident during an emergency that requires dependence on the dc system.
Charging — The normal float charge voltage is a critical factor in maintaining the battery. Control of this voltage is necessary to prevent overcharge or undercharge problems, described below:

1. Excessive Charging
   • Produces increased amounts of gas
   • Increase water consumption
   • Corrodes the positive-plate grids
   • Shortens life

2. Insufficient charging
   • Decrease the specific gravity of the electrolyte
   • Allows a buildup of sulfate on the plates
   • Reduces capacity
   • Shortens life

The correct charge rate must be used throughout the life of the battery. Damage is cumulative and is never repaired by better charging procedures later. The primary indications of correct charging are constant specific gravity, constant voltage, and normal water consumption. If any of these change, the reasons for the change should be investigated and corrective action taken. If one or more cells are removed from service, the float charge voltage must be adjusted for the new total voltage.

Extended periods of insufficient float voltage are usually indicated by low specific gravity and excessive sulfation crystals on the plates. Overcharging causes corrosion of the positive-plate grid structures and, if allowed to continue, will eventually destroy the cell through plate growth. Elevated cell temperature and increased water consumption are indications of excessive charging current.

It is usually necessary to return about 10% more ampere hours during charging than are used during discharge.
In the event that a cell cannot sustain a charge or maintain voltage level, it should be immediately disconnected from the battery, pending replacement. During the period when the total number of cells is changed, the charger settings must also be changed to reflect the new voltage requirements. In this instance, the desired voltage per cell does not change, but the value is multiplied by the new total number of cells to determine the charger output voltage.

Cell and battery voltages change with electrolyte temperature and should be corrected in accordance with the manufacturer’s instructions. The correction is typically 0.003 V/cell for each degree Fahrenheit.

**Water** — Water must be added to the cells from time to time. The electrolyte-level indicator on each cell should be observed monthly, and the level kept between the midpoint and the high-level mark when the cell has normal voltage and is at ambient temperature. This midpoint electrolyte level can change not only through loss of water due to electrolysis and evaporation but also during charging when gassing within the electrolyte produces the appearance of additional liquid because of the presence of gas bubbles. The manufacturer’s recommendation concerning the addition of water should be rigidly observed.

**Visual Inspection** — The battery cells should be visually checked for any signs of jar cracks, brazing, leaking electrolyte, electrolyte creepage around the terminal posts, electrolyte on the top of the cover, sulfation of the cell posts or the intercell connectors, excessive dust or other debris on top of the cells, scaly particles on the edges of the plates within the cell, or excessive deposits at the bottom of the cells.

Lead-coated parts that are external to the cell may become discolored; the discoloration is sometimes interpreted as lead sulfate when it is really hydrated lead. Lead hydrate is formed when water reacts with lead and does not harm the battery.
During visual inspections of the rack, the rack and the floor should be examined for signs of electrolyte leakage. The structural members of the rack should be checked for signs of corrosion.

The electrolyte levels in all cells should be checked. The electrolyte should always completely cover the plates and normally indicate between the High and Low marks on the side of the clear Battery case.

Satisfactory operation of the battery room ventilation system should be observed.

The torque of the intercell connector bolts should be checked only if intercell connection resistance measurements indicate that this is necessary. Stress is applied to the cell posts and post seal when retorquing.

The individual cells should be clean and dry. Clear water, rather than detergents, solvents, or petroleum-based cleaning agents, should be used to remove normal deposits of dust or dirt. Water minimizes the possibility of damaging the plastic cells. Electrolyte spills should be neutralized with a baking soda-and-water solution, which is then removed. Under extreme conditions, the cell can be shorted by dirt, standing water, or baking soda residue on the tops of the cell.

Measurement Of Intercell Connection Resistance — Intercell resistance measurements should be made as soon as possible after the installation of the battery. These measurements establish a benchmark value for future testing. If, during subsequent measurements, the intercell resistance exceeds the benchmark value of 20%, or exceeds a ceiling value established by the manufacturer, that particular intercell connector should be disassembled, cleaned, and reinstalled as it was in the original installation procedure. The intercell resistance should then be measured again.
**Measurement Of Specific Gravity** — The specific gravity of the electrolyte is the ratio of the weight of the electrolyte to the weight of the same volume of distilled water; in the case of lead-acid batteries, it is the ratio of the weight of a solution of sulfuric acid and water to the weight of the same volume of water. This assumes a homogeneous concentration within the electrolyte. Typically, the electrolyte is approximately 30% acid and 70% water.

It is important to take, at specified intervals, specific gravity readings of one or all cells. Each battery is supplied with an electrolyte with a nominal specific gravity of 1.210 or 1.215 for lead-calcium cells. A satisfactory specific gravity reading for a cell with a nominal specific gravity of 1.215 can vary between 1.210 and 1.220 while the cell is fully charged. A consistent specific gravity reading for each cell over a long period of time is an indication of a good cell. A faster-than-average reduction in specific gravity is a reason to question the cell's capability. Specific gravity readings should be corrected to reflect average cell temperatures. For every 3°F above 77°F, 0.001 should be added to the observed reading. For every 3°F below 77°F, 0.001 should be subtracted from the reading.

The specific gravity can change with electrolyte level, since the loss of water by electrolysis and evaporation can increase the acid concentration. Deviations as little as ⅛" may change the specific gravity reading by 0.003. The battery manufacturer can provide specific gravity correction values for a given cell based on the volume of electrolyte and the physical dimensions of the container.

Specific gravity readings should be taken when the level is greater than minimal. Readings should not be taken immediately after adding water, because there may not be complete diffusion of the water into the electrolyte. It may be several weeks after water addition before the electrolyte is homogeneous.
The solution in large lead-acid batteries is not always homogeneous for other reasons. While the battery is being charged, the lead sulfate that was formed during the discharge cycle reverts to lead oxide and sulfuric acid. The fresh acid that is formed during the charging cycle has a higher specific gravity and settles to the bottom of the cell. If there is nothing to mix the electrolyte, there will be a specific gravity gradient in the cell; the specific gravity at the bottom of the cell will be higher than that at the top.

Lead-calcium cells, with much less water loss and the attendant reduction of gas production, exhibit a much greater specific gravity gradient. The Battery manufacturer has therefore placed an electrolyte withdrawal tube one-third to one-half the way up from the bottom of the cell; measurements from this point provide a better approximation of a homogeneous concentration of the specific gravity of the cell electrolyte. However, a more accurate measurement of the specific gravity can be obtained if it is measured at three points - at the top of the electrolyte, through the electrolyte withdrawal tube, and at the bottom of the cell - and the readings are averaged.

The reason for measuring the specific gravity is to estimate the cell's state of charge. As the cell charges, the specific gravity increases, then levels off as full charge for the applied potential is reached. The charging current decreases to the finishing rate as a full state of charge is reached. The battery is considered fully charged when all the lead sulfate is returned to lead oxide and sulfuric acid and the charging current is stabilized. The battery is considered fully discharged when the cells are heavily coated with lead sulfates. See Figure GS3.5.
SYSTEM OPERATION

Normal Operation

All three 125 VDC power subsystems function in a similar manner during normal operation under all power plant operating modes. The 125 VDC loads on all three subsystems are supplied power from their respective battery chargers with their batteries on a float charge. This means that the batteries are continuously maintained in a fully or almost fully charged condition. When floating, the batteries receive a continuous charge at an extremely low rate. The charging rate is just enough to counteract the small internal losses that are present in every type of storage battery.

Abnormal Operating Conditions For Class 1E

The control room operator is alerted to abnormal conditions within the class 1E DC system by various annunciators located on MCB Panels XCP-636 ('A' Train) and XCP-637 ('B' Train). The annunciators and probable cause for the annunciator are described below with operator corrective actions contained in the respective ARP.

<table>
<thead>
<tr>
<th>DGA(B)</th>
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<tbody>
<tr>
<td>LOSS OF DC</td>
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</table>

**PROBABLE CAUSE:**
1. FU-1,2,3 or 4 blown in XPN-5503 (DB-427).
2. FU-11 or FU-16 blown in XCX-5201 (DB-436).
3. DPN1HA1 13, XCX-5201 DSL GEN A CONT CUBICLE, tripped.
4. DPN1HA1 14, XPN-5301 DSL GEN A EGN CONT RELAY & TERM PNL, tripped.
5. Loss of DC bus DPN1HA.
6. Relay failure
AUTOMATIC ACTIONS:

1. Disables the automatic starting capability of Diesel Generator A.
2. If DPN1HA1 13, 1A DIESEL GEN CONT PNL XCX5201, has tripped:
   a. Disables both automatic and manual Diesel Generator start capability.
   b. Annunciator DG A ANNUN GND/PWR FAIL (XCP-636 3-6) alarms.
3. If DPN1HA1 14, XPN 5503-DG A RELAY & TERMINAL PANEL, has tripped:
   a. Both automatic and manual pushbutton Diesel Generator start capability is prevented due to the inability to energize start relays.
   b. If Diesel Generator A is running, the following features are lost:
      1) The ability to shutdown the diesel engine by placing the TEST Switch in STOP (MCB) or by depressing the STOP Pushbutton (Local).
      2) Diesel Engine protective trips are disabled due to the inability to energize XVX10998A-DG, AIR TO FUEL RACK S/D CYL SOLENOID VALVE.

| TRAIN A(B) |
| BATT CHGR |
| TRBL XBC1A(B)/1A-1B |

PROBABLE CAUSE:

1. One of the following conditions for the in-service charger:
   a. CB1 trip (AC input).
   b. CB2 trip (DC output).
   c. Fan failure.
   d. Low DC voltage.
   e. AC power failure.

| DC SYS |
| TRAIN A(B) |
| GND TRBL |

SETPOINT:
High: 5mA after 10 second time delay
Low: 2.5 mA after 450 second time delay
PROBABLE CAUSE (Attachment II Page 2) (637 4-5 = Train B):

1. High-Ground on the positive or negative leg of DPN1HA (1HB).

2. Low:
   a. Ground on both legs of DPN1HA (1HB).
   b. Blown fuse in the ground detector circuit.

<table>
<thead>
<tr>
<th>DC SYS</th>
<th>SETPOINT:</th>
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<tbody>
<tr>
<td>OVRVOLT</td>
<td>Overvoltage 140 VDC</td>
</tr>
<tr>
<td>UNDRVOLT</td>
<td>Undervoltage 126 VDC</td>
</tr>
</tbody>
</table>

PROBABLE CAUSE:

1. Overvoltage:
   a. Failure of voltage regulating circuit on XBC1A (1B) or XBC1A/1B.
   b. Misadjustment of equalize voltage pot on XBC1A (1B) or XBC1A/1B.

2. Undervoltage:
   a. Blown fuse in undervoltage relay circuit on DPN1HA (1HB).
   b. Battery charger failure and excessive battery loading.

PROBABLE CAUSE:

1. One of the following breakers tripped:
   a. DPN1HA3, (1HB3), 01, CONTROL POWER FOR XSW1EA (1EB).
   b. DPN1HA1 (1HB1), 01, CONT POWER FOR XSW1DA (1DB).
   c. DPN1HA3 (1HB3), 26, DPN1HA3 (1HB3).
   d. DPN1HA (1HB) 19, DPN1HA1 (1HB1).
PROBABLE CAUSE:
1. One of the following breakers tripped:
   a. DPN1HA1 (1HB1) 02, CONT POWER FOR XSW1DA1 (1DB1).
   b. DPN1HA1 (1HB1) 03, CONT POWER FOR XSW1DA2 (1DB2).
   c. DPN1HA3 (1HB3) 02, CONTROL POWER FOR XSW1EA1 (1EB1).
   d. DPN1HA (1HB) 19, DPN1HA1 (1HB1).
   e. DPN1HA (1HB) 26, DPN1HA3 (1HB3).

Abnormal Operating Conditions For Non-Class 1E

The control room operator is alerted to abnormal conditions within the non-class 1E DC system by various annunciators located on MCB Panel XCP-635 (‘X’ Train). The annunciators and probable cause for the annunciator are described below with operator corrective actions contained in the respective ARP.

PROBABLE CAUSE:
1. Breaker trip.
2. Fan Failure
3. Low DC Voltage.
4. AC Power Failure.
5. Positive or negative to ground.
DC SYS
TRAIN X
GND TRBL

SETPOINT:
High: 5mA after 5 second time delay
Low: 2.5mA after 450 second time delay

PROBABLE CAUSE (Attachment II Page 1):
1. High - Ground on the positive or negative leg of DPN1HX.
2. Low:
   a. Ground on both legs of DPN1HX
   b. Blown fuse in the ground detector circuit.

DC SYS
TRAIN X
UNDERVOLT

SETPOINT:
126 VDC

PROBABLE CAUSE:
1. Blown fuse in the undervoltage relay circuit on DPN1HX.
2. Battery charger failure and excessive battery loading.

7.2KV
BOP BUSSSES
LOSS OF DC

PROBABLE CAUSE:
1. DC Power supply breaker open at DPN1HX3 01, 03, 05 13, or 14 (436TB).
2. DC Power breaker open at switchgear.
Abnormal Operating Conditions For Switchyard Non-Class 1E

The control room operator is alerted to abnormal conditions within the switchyard non-class 1E DC system by various annunciators located on MCB Panel XCP-638. The annunciators and probable cause for the annunciator are described below with operator corrective actions contained in the respective ARP.

**BATT CHG FAIL**

**PROBABLE CAUSE:**
1. Loss of one or both battery chargers.
2. Fan failure on one or both battery chargers.
3. Loss of AC power to battery chargers.

**BATT VOLT LO**

**SETPOINT:**
105 VDC

**PROBABLE CAUSE:**
1. Loss of one or both battery chargers.

**Infrequent Operations For Class 1E And Non-Class 1E**

Occasionally, infrequent operations within the DC system must be performed to realign the DC system to meet operational needs or to respond to a failure within the system. The following is a list of infrequent operations that are performed per SOP-311, as necessary, to meet operational needs:

A. Removing battery charger from service (XBC1X, 1X-2X, 1A, 1B, or 1A-1B)
B. Removing a battery from service (XBA1X, 1A or 1B)
C. Removing a 125 VDC distribution panel from service (DPN1HX, 1HA, or 1HB)
D. Placing a BOP battery charger in service (XBC1X or XBC1X-2X)
E. Placing an ESF battery charger in service (XBC1A or XBC1B)
F. Placing swing battery charger XBC1A-1B in service for distribution panel 1HA or 1HB
G. Placing a battery in service (XBA1X, 1A or 1B)
H. Placing 125 VDC BOP distribution panel 1HX in service
I. Placing a 125 VDC ESF distribution panel in service 1HA or 1HB)
J. Placing a switchyard battery charger in service
K. Removing a switchyard battery charger from service
L. Placing the switchyard battery bus on alternate feed
M. Placing the switchyard battery bus on normal feed
N. Supplying temporary power to swing battery charger XBC1A-1B

**Emergency Operation**

A Loss of Coolant Accident (LOCA) coincident with a loss of offsite power (LOOP) is the worst DBA for Class 1E 125V dc system. This DBA analysis is based on the capability of Class 1E 125V dc batteries and the battery chargers to support the assumed loads on the dc system to achieve plant shutdown and to mitigate this design basis accident, in accordance with FSAR commitments and Technical Specification requirements.

When a loss of offsite AC power occurs, all the loads on the three DC power subsystems are transferred to their respective batteries. The emergency diesel generators restore AC power to the Safeguards Power System upon a loss of offsite AC power. This in turn reenergizes the battery chargers for the Class 1E and non-Class 1E DC power subsystems and recharges the batteries. If an extended AC outage (Blackout) occurs, less critical loads should be disconnected as soon as possible to conserve the battery. The class 1E batteries are sized to maintain the vital 120 VAC loads for four hours without charging. Each class 1E battery is required to supply a minimum end-of-discharge voltage of 108 volts dc at the end of a four hour duty cycle
with 58 cells in service. The switchyard 125 VDC power subsystem battery chargers remain deenergized. A manual transfer of power to DC panel DPN-1S from its battery supply to its emergency supply (DPN-1HX) has to be performed when the battery becomes discharged and offsite power cannot be restored. An alternative is to restore power to the switchyard DC power battery chargers by reenergizing switchgear unit 1B1 from the Safeguards Power System, via the appropriate crosstie circuit breaker.

**Operation with DC Grounds**

A low resistance to ground from either the positive or negative side of the class 1E 125 VDC system causes a high current to ground indication, which in turn causes a computer DC ground alarm and a MCB annunciator. The developing short must be isolated and corrected as soon as possible to maintain the operability of the safeguards equipment. Electrical maintenance personnel will assist in the location and isolation of grounds.

Operation with DC grounds can result in safeguards equipment failing to operate when needed or operating spuriously. The reliability of equipment in the Intermediate Building which may be exposed to a harsh environment during a steamline or feedwater line break has been improved by the addition of remote (CB) relays to remove DC control power from these components. Since safeguards equipment is generally designed to "fail-safe" to its required position (containment isolation valves close, etc), removal of control power (pulling fuses, etc) is one way to get a component that has failed to operate into its required position. The best course is to prevent this situation by keeping the DC systems free of grounds.

Severe DC grounds or exhaustion of the safeguards batteries (four hours after a loss of all AC) leads to a total loss of DC power. Two major consequences of a loss of DC are a loss of vital instrument action (due to loss of DC power to the vital inverters) and inability to start the DG (loss of field flash and control power). The simultaneous operation of many components and loss of component position and parameter
(temperature, pressure, etc.) indication make loss of DC one of the most severe, and most difficult to manage, accidents.

Effects of a loss of 1HA, 1HB, 1HX or any subpanel/component are identified in SS-200-963 (GMP112 Feeder List) Feeder Effects List.

**In-House And Industry Operating Experience**

This section is organized to provide effective use of in-house and industry operations experience, including component failure data, to improve plant safety and reliability. Detailed information on INPO case studies or In-house/Industry Operating Experience is contained in the respective document. The following summary of Operating Experience and Referenced Events should be reviewed for applicability to VCS.

- **INPO 87-012 (Loss Of Power To The Integrated Control System Leading To An Overcooling Transient)**

Control power was lost to the integrated control system, a non-safety-related system while the reactor was operating at 76 percent power. This resulted in a rapid reduction of main feedwater flow, following by a reactor trip on high reactor coolant system pressure and automatic initiation of the auxiliary feedwater system. Additionally, without integrated control system power, auxiliary feedwater flow to the steam generators and steam flow through the atmospheric dump valve and turbine bypass valves could not be controlled from the control room. Auxiliary feedwater flow, together with this steam flow, produced an excessive and rapid reactor coolant system cooldown and depressurization, sufficiently to automatically initiate the safety features actuation system. High pressure injection flow resulted in subsequent reactor coolant system repressurization while temperature was still decreasing.
A detailed chronology of the event is presented in INPO 87-012 Attachment A. Attachment B is a description of the key plant systems that were involved in this event. Attachment C describes earlier events that had lessons appropriate to the December 26, 1985 overcooling event.

- **SOER 81-15 (Partial Loss of DC Power) (Millstone 2)**
  - An Operator inadvertently rotated the control switch for the DC System A Battery Bus Main Breaker while taking ground readings. Several consequences of this event were identified.
    - Reactor Trip
    - Failure of the turbine to trip on a reactor trip resulting in excessive plant cooldown.
    - Loss of power to control room annunciators (Blown fuses due to use of improper fuses)
    - Failure of the generator breaker to auto open
    - Failure of the Auto Fast Transfer of AC Buses to the Reserve Station Service Transformer.
    - The B Train Diesel Generator tripped after 10 minutes due to a Service Water Leak wet the control panels.
    - The operating crew was not aware of that they did not have pressurizer spray with their current pump configuration
  - DC power was restored within 51 seconds of initiation of the event. AC Buses transferred to Alternate Power Supplies with Condensate Pumps and Reactor Coolant Pump Breakers Still closed which resulted in over current condition with resultant bus de-energizing.

- **SOER83-5 (DC Power System Failures) (5 Plants)**
  - Vital DC power failures due to personnel errors, lack of adequate procedures, and internal component failures have resulted in inadvertent reactor trips and severe operational transients at operating nuclear power plants.
Zion 2- Personnel error opening breaker results in unanalyzed system interactions and responses, severe equipment damage, loss of system status information, a severe cooldown and entry into the emergency plan.

Palisades- maintenance personnel opened both battery output breakers for one hour during performing monthly surveillance testing. There were no alarms so control room personnel were unaware of these actions.

Fort Calhoun- Solenoid valve coils fail due to high voltage during battery equalizing charge.

Fitzpatrick- Erratic reading on nuclear instruments due to discharge of the DC bus battery during maintenance of the battery charger.

Brunswick 1- Rapid drop in voltage during start of a battery discharge test due to loose and oxidized connectors.

**Technical Specifications**

The applicable Technical Specification sections pertaining to the class 1E DC system are as follows and should be reviewed for impact on continued plant operations: (See Attachment I)

1. 3.8.2.1 D.C. Sources (Modes 1, 2, 3, and 4)
2. 3.8.2.2 D.C. Sources (Modes 5 and 6)

**Bases**

1. 3.8.2.1 D.C. Sources (Modes 1, 2, 3, and 4) - The OPERABILITY of the A.C. and D.C. power sources and associated distribution systems during operation ensures that sufficient power will be available to supply the safety-related equipment required for 1) The safe shutdown of the facility and 2) The mitigation and control of accident conditions within the facility. The minimum specified independent and redundant A.C. and D.C. power sources and distribution...
systems satisfy the requirements of General Design Criterion 17 of Appendix 'A' to 10CFR50.

2. 3.8.2.2. Sources (Modes 5 and 6) – The OPERABILITY of the minimum specified A.C. and D.C. power sources and associated distribution systems during shutdown and refueling ensures that 1) the facility can be maintained in the shutdown or refueling condition for extended time periods and 2) sufficient instrumentation and control capability is available for monitoring and maintaining the unit status.
SUMMARY

The DC Power System consists of three separate 125 VDC subsystems: the Class 1E, the non-Class 1E, and the switchyard 125 VDC power subsystems. Each one is designed to provide a continuous, reliable source of electrical power to its specific category of DC loads. All three subsystems of the DC Power System combine an arrangement of batteries, battery chargers, and distribution panels to achieve their respective subsystem function.

The Class 1E subsystem is reactor safety related and is divided into two independent and redundant trains. Each train has identical components and similar loads. Its design complies with General Design Criteria 17 of 10 CFR 50, Appendix A. Only one of the two trains is needed to ensure that the Engineered Safety Features systems provide sufficient reactor protection during accident and normal operating conditions.

The non-Class 1E and the switchyard 125 VDC power subsystems are not reactor safety related. Each consists of only one train of equipment and electrical circuits similar to one train of the Class 1E subsystem.

Batteries (SOP-311):

- ESF Battery Capacities:
  - 8 hour rate – 2100 AH (to 108 volts with 60 cells)
  - 4 hour rate – 1770 AH (to 108 volts with 60 cells)
  - 4 hour rate – 1470 AH (to 108 volts with 58 cells)
  - 1 hour rate – 982 AH (to 108 volts with 60 cells)
- BASIS – the ESF Batteries are sized to provide continuous power during a worst case four hour duty cycle. The capacity evaluation was based on a final battery terminal voltage of 108 VDC or greater which provides sufficient margin to ensure device operability with a reduction of up to 2 cells (58 cells connected) on either battery. Further, the evaluation assumes no load shedding or operator action during the four hour duty cycle.
  - General Information:
    - Each battery contains 60 cells
    - Cells are the lead-calcium type
    - Designed for continuous float duty

After studying this text, the student should review the text’s learning objectives and answer the self-assessment questions.
1. Adequate protective clothing must be worn (i.e., chemical suit or apron and goggles or face shield) when sampling or handling strong acid solution.

2. Water should never be added to strong acid solutions. Acid should be added to water instead.

3. Concentrated sulfuric acid (specific gravity 1.830) should never be added to a battery, as overheating may result.

4. Tripped breakers on DPN1HX, BATTERY MAIN DISTRIBUTION PANEL 1HX (IB-412), and DPN1HX3, 125 V DC DISTRIBUTION PANEL 1HX3 (TB-436), should not be reset without Electrical maintenance evaluation to determine if the breaker fault protection has been lost by experiencing a fault current greater than nameplate value.

5. Parallel Battery Charger operations should be avoided when the Battery is disconnected from the bus.
REFERENCES

1. Virgil C. Summer Nuclear Station, Final Safety Analysis Report, ch. 8. (8, 3, 2)

2. Virgil C. Summer Nuclear Station, Operating Procedures, SOP-311.

3. GAI Drawing Nos:
   - E-201-332
   - E-201,334
   - E-206-61 Sh 1
   - E-206-61 Sh 2
   - E-206-62 Sh 1 & 2
   - E-206-62 Sh 3
   - E-229-025,

4. Westinghouse Electrical Sciences Lesson Text, ch. 2.


6. MRF 21502, Larger Substation battery XBA 1S-TS.

7. MRF 21558, D.C. Ground Detector.

8. MRF 21595, Upgraded Class 1E batteries.

9. MRF 32942, Revised battery room vent damper trip setpoints.

10. LER 88-12 and IN 88-86, Multiple Grounds in DC Distribution Systems.

11. Simulator Integrated Systems Tests IST-6.6.7.1 (1HA) and IST-6.6.7.2 (1HB).

12. 1MS-94B-1253, Standby Battery.

13. MRF-21432, which replaced the vital inverters and deleted DC input power to inverters XIT-5907 and XIT-5908.
14. MRF-21538, which supplied DC Trip Power for RCP A, B, C breakers from DPN-1HB2 (through isolation fuse panel XPN-4254).

15. LER 90-006, Diesel Generator Actuation Due to Personnel Error in Terminating Battery.


17. SOER 83-5, DC Power System Failure.

18. INPO-87-012, Loss of Power to the Integrated Control system leading to an overcooling transient.


SELF-ASSESSMENT QUESTIONS

1. State the function of each of the three 125 VDC power subsystems.

2. Draw a basic diagram of the layout of the Class 1E 125 VDC power subsystem.

3. What is the capacity of the battery chargers in the Class 1E and non-Class 1E 125 VDC power subsystems based on?

4. Why are the batteries of the Class 1E subsystem located in separate rooms?

5. What are the capacities of the Class 1E and non-Class 1E batteries?

6. What are the control room indications for Class 1E and non-Class 1E battery conditions?
7. What are the power supplies to the switchyard 125 VDC power battery chargers?

8. What is meant by floating the battery?

9. Draw a diagram of the non-Class 1E DC power subsystem.

10. Draw a diagram of the switchyard DC power subsystem.

11. Describe the construction of the internals of a lead-acid battery cell.

12. What materials are the positive and negative plates made of?

13. What liquid is used as the electrolyte in the Virgil C. Summer storage batteries?
14. What chemical reactions take place at the positive and negative plates of a battery cell during a discharge of the battery?

15. How do the storage batteries operate in conjunction with the battery chargers during normal operation?

16. As maintenance is being performed on the switchyard battery, offsite power is lost and cannot be restored. How can the switchyard DC power distribution panels be reenergized?
ELECTRICAL POWER SYSTEMS

3/4.8.2 D.C. SOURCES

OPERATING

LIMITING CONDITION FOR OPERATION

3.8.2.1 As a minimum the following D.C. electrical sources shall be OPERABLE:

a. 125-volt Battery bank No. 1A and its associated full capacity charger.

b. 125-volt Battery bank No. 1B and its associated full capacity charger.

APPLICABILITY: MODES 1, 2, 3 and 4.

ACTION:

a. With one of the required battery banks inoperable, restore the inoperable battery bank to OPERABLE status within 2 hours or be in at least HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

b. With one of the required full capacity chargers inoperable, demonstrate the OPERABILITY of its associated battery bank by performing Surveillance Requirement 4.8.2.1.a.1 within one hour, and at least once per 8 hours thereafter. If any Category A limit in Table 4.8-2 is not met, declare the battery inoperable.

SURVEILLANCE REQUIREMENTS

4.8.2.1 Each 125-volt battery bank and charger shall be demonstrated OPERABLE:

a. At least once per 7 days by verifying that:

1. The parameters in Table 4.8-2 meet the Category A limits, and

2. The total battery terminal voltage is greater than or equal to 129 volts on float charge.
ELECTRICAL POWER SYSTEMS

SURVEILLANCE REQUIREMENTS (Continued)

b. At least once per 92 days and within 7 days after a battery discharge with battery terminal voltage below 110-volts, or battery overcharge with battery terminal voltage above 150-volts, by verifying that:

1. The parameters in Table 4.8-2 meet the Category B limits,
2. There is no visible corrosion at either terminals or connectors, or the connection resistance of these items is less than $150 \times 10^{-6}$ ohms, and
3. The average electrolyte temperature of 10 of the connected cells is $> 60^\circ$F.

c. At least once per 18 months by verifying that:

1. The cells; cell plates and battery racks show no visual indication of physical damage or abnormal deterioration,
2. The cell-to-cell and terminal connections are clean, tight, and coated with anti-corrosion material,
3. The resistance of each cell-to-cell and terminal connection is less than or equal to $150 \times 10^{-6}$ ohms, and
4. The battery charger will supply at least 300 amperes at 132 volts for at least 8 hours.

d. At least once per 18 months, during shutdown, by verifying that the battery capacity is adequate to supply and maintain in OPERABLE status all of the actual or simulated emergency loads for the design duty cycle when the battery is subjected to a battery service test.

e. At least once per 60 months, during shutdown, by verifying that the battery capacity is at least 80% of the manufacturer's rating when subjected to a performance discharge test. This performance discharge test may be performed in lieu of the battery service test required by Surveillance Requirement 4.8.2.1.d.

f. Annual performance discharge tests of battery capacity shall be given to any battery that shows signs of degradation or has reached 85% of the service life expected for the application. Degradation is indicated when the battery capacity drops more than 10% of rated capacity from its average on previous performance tests, or is below 90% of the manufacturer's rating.
TABLE 4.8-2

BATTERY SURVEILLANCE REQUIREMENTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CATEGORY A (1)</th>
<th>CATEGORY B (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Limits for each designated pilot cell</td>
<td>Limits for each connected cell</td>
</tr>
<tr>
<td>Electrolyte Level</td>
<td>&gt; Minimum level indication mark, and ≤ ¼&quot; above maximum level indication mark</td>
<td>&gt; Minimum level indication mark, and ≤ ¼&quot; above maximum level indication mark</td>
</tr>
<tr>
<td>Float Voltage</td>
<td>≥ 2.13 volts</td>
<td>≥ 2.13 volts (c)</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>≥ 1.200 (b)</td>
<td>≥ 1.195</td>
</tr>
</tbody>
</table>

(a) Corrected for electrolyte temperature and level.
(b) Or battery charging current is less than (2) amps when on charge.
(c) Corrected for average electrolyte temperature.

(1) For any Category A parameter(s) outside the limit(s) shown, the battery may be considered OPERABLE provided that within 24 hours all the Category B measurements are taken and found to be within their allowable values, and provided all Category A and B parameter(s) are restored to within limits within the next 6 days.

(2) For any Category B parameter(s) outside the limit(s) shown, the battery may be considered OPERABLE provided that the Category B parameters are within their allowable values and provided the Category B parameter(s) are restored to within limits within 7 days.

(3) Any Category B parameter not within its allowable value indicates an inoperable battery.
ELECTRICAL POWER SYSTEMS

D.C. SOURCES

SHUTDOWN

LIMITING CONDITION FOR OPERATION

3.8.2.2 As a minimum, one 125-volt battery bank and its associated full capacity charger shall be OPERABLE.

APPLICABILITY: MODES 5 and 6.

ACTION:

a. With the required battery bank inoperable, immediately suspend all operations involving CORE ALTERATIONS, positive reactivity changes or movement of irradiated fuel; and initiate corrective action to restore the required battery bank to OPERABLE status as soon as possible.

b. With the required full capacity charger inoperable, demonstrate the OPERABILITY of its associated battery bank by performing Surveillance Requirement 4.8.2.1.a.1 within one hour, and at least once per 8 hours thereafter. If any Category A limit in Table 4.8-2 is not met, declare the battery inoperable.

SURVEILLANCE REQUIREMENTS

4.8.2.2 The above required 125-volt battery bank and charger shall be demonstrated OPERABLE per Surveillance Requirement 4.8.2.1.
PANEL XCP-635
ANNUNCIATOR POINT 4-2

SETPOINT:
High: 5 mA after
5 second time delay
Low: 2.5 mA after
450 second time delay

ORIGIN:
AMMETER IAM5492

PROBABLE CAUSE:

1. High - Ground on the positive or negative leg of DPN1HX.
2. Low:
   a. Ground on both legs of DPN1HX.
   b. Blown fuse in the ground detector circuit.

AUTOMATIC ACTIONS:

1. None.

CORRECTIVE ACTIONS:

OA 1. Dispatch an operator to XPN5554(IB-412) to perform the following:
   a. Depress the MODE Pushbutton three times to display the high set limit and
      release.
   b. Within five seconds and while the high set limit is being displayed, depress the
      SET Pushbutton.
   c. Depress the MODE Pushbutton four times to display the low set limit and
      release.
   d. Within five seconds and while the low set limit is being displayed, depress the
      SET Pushbutton.

SUPPLEMENTAL ACTIONS:

1. If the alarm returns immediately after the appropriate time delay has passed, direct
   Electrical Maintenance to perform EMP-115.009.

REFERENCES:

2. B-209-376.
3. 1MS-94B-1276.
4. EMP-115.009.
## PANEL XCP-636
### ANNUNCIATOR POINT 4-5

<table>
<thead>
<tr>
<th>DC SYS</th>
<th>TRAIN A</th>
<th>GND TRBL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SETPOINT:</strong></td>
<td></td>
<td><strong>ORIGIN:</strong></td>
</tr>
<tr>
<td>High: 5 mA after 10 second time delay</td>
<td></td>
<td>AMMETER IAM5490</td>
</tr>
<tr>
<td>Low: 2.5 mA after 450 second time delay</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PROBABLE CAUSE:</strong></td>
<td></td>
<td><strong>CHG</strong></td>
</tr>
<tr>
<td>1. High - Ground on the positive or negative leg of DPN1HA.</td>
<td></td>
<td><strong>B</strong></td>
</tr>
<tr>
<td>2. Low:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Ground on both legs of DPN1HA.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Blown fuse in the ground detector circuit.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AUTOMATIC ACTIONS:</strong></td>
<td></td>
<td><strong>CHG</strong></td>
</tr>
<tr>
<td>1. None.</td>
<td></td>
<td><strong>C</strong></td>
</tr>
<tr>
<td><strong>CORRECTIVE ACTIONS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Dispatch an operator to XPN5439 (IB-412) to perform the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Depress the MODE Pushbutton three times to display the high set limit and release.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Within five seconds and while the high set limit is being displayed, depress the SET Pushbutton.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Depress the MODE Pushbutton four times to display the low set limit and release.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Within five seconds and while the low set limit is being displayed, depress the SET Pushbutton.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SUPPLEMENTAL ACTIONS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. If the alarm returns immediately after the appropriate time delay has passed, submit an MWR to Electrical Maintenance.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>REFERENCES:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. B-208-030, ED-01 and ED-05.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. 1MS-94B-1276.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. EMP-115.009.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SWITCHYARD DC POWER SUBSYSTEM

* An Emergency Feed from DPN - 1 Hx provides DC Power should AC Power be LOST while the battery (XBA-15) is out of service. Fuse holders in the feeder line from panel DPN - 1Hx are located in panel DPN - 1S and have their fuses removed for normal operation.

FIGURE GS3.2
LEAD-ACID STORAGE BATTERY CHEMICAL ACTION

**Fully Charged**
- Spongy Lead, Pb
- Lead Peroxide, PbO₂

**Fully Discharged**
- Minimum Pb, Heavily Lead Sulfate Coated
- Minimum PbO₂, Heavily Lead Sulfate Coated

**Discharging**
- Load
- Electrons
- Sulfuric Acid Changes to Lead Sulfate on Plates
- Spongy Lead Decreasing
- Lead Sulfate Increasing
- Sulfuric Acid Decreasing
- Water Increasing

**Charging**
- Electrons
- Lead Sulfate on Plates Goes Back to Solution as Sulfuric Acid
- Spongy Lead Increasing
- Lead Sulfate Decreasing
- Sulfuric Acid Increasing
- Water Decreasing

Figure GS3.5
BATTERY CHARGER (SIMPLIFIED)

480 VAC
3Ø, 60 Hz

NC

Undervoltage Relay

Rectifier

Voltmeter (Local)

Undervoltage and Overvoltage Relays

Ground Relays

Voltage Regulator and Control

Shunt

Ammeter (MCB)

125 VDC

Figure GS3.6