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[2156] From:  COMNAVSEASYSCOM WASHINGTON DC//03E// at Intxch 2/29/96 2:09PM (192
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Subject: 280316Z FEB 96; R;NSTM CHAPTER 223 V1 ACN 3A//
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Text item  1: Text Item

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TO RUCBCLF/CINCLANTFLT NORFOLK VA//JJJ//
RHHMHAH/CINCPACFLT PEARL HARBOR HI//JJJ//
RUCBKMC/COMSUBLANT NORFOLK VA//N40//
RHHMDBA/COMSUBPAC PEARL HARBOR HI//N40//
RUWFPBC/NAVSURFWARCENDIV PORT HUENEME CA//5B31//
INFO RULSSEA/COMNAVSEASYSCOM WASHINGTON DC//
     03E/03E1/03E12/03E21/08K/92/
     PMS390/PMS393/PMS395/PMS396//
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SUBJ/NSTM CHAPTER 223 V1 ACN 3A//
RMKS/1.  THIS MESSAGE COMPRISES ADVANCED CHANGE NOTICE (ACN) 3/A
(NSDSA CONTROL NO. A46705) TO NSTM CHAPTER 223,
NAVSEA 0986-G1-STM-010/CH223, VOL 1, REV 2.
2.  SPECIFIC MODIFICATION TO THE SUBJECT MANUAL IS ON PAGE 138,
PARAGRAPH 223-5.5.2.2 HYDROGEN DETECTORS.  DELETE THE TEXT AND
SUBSTITUTE WITH:  "PRIOR TO EACH EQUALIZING CHARGE, CHECK THAT THE
PAGE 02 RUCBSGG1740 UNCLAS
CALIBRATION DATE OF THE HYDROGEN DETECTORS IS CURRENT PER THE
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3.  THE NAVSEA TECHNICAL POINT OF CONTACT (TPOC) IS MR. JAMES L.
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S9086−G1−STM−010/CH−223

SECOND REVISION

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 223
VOLUME 1

SUBMARINE STORAGE BATTERIES LEAD ACID BATTERIES

THIS CHAPTER SUPERSEDES CHAPTER 223 VOLUME 1 REVISION 1 DATED 15 NOVEMBER 1984

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CHAPTER 223
SUBMARINE STORAGE BATTERIES
VOLUME 1, LEAD ACID BATTERIES

SECTION 1.
DESCRIPTION

223−1.1 THEORY OF LEAD ACID STORAGE BATTERY

Although a storage battery supplies electrical energy on discharge and receives electrical energy on charge, it stores chemical energy, not electrical energy. On discharge, the chemical energy stored in the battery is converted into electrical energy, which is delivered to an external circuit. During the discharge, the active materials in the battery are converted into inactive materials that can no longer supply electrical energy. To restore the battery to a charged condition, electrical energy from an outside source is supplied to the battery, a current is forced through it in a direction opposite the current flow on discharge, and the inactive materials are converted to active materials that can again deliver electrical energy. This is known as charging. Hence, on discharge, chemical energy is converted into electrical energy; on charge, electrical energy is converted into chemical energy. The direction of current flow in the external circuit connecting the battery terminals is from the positive electrodes (plates) on discharge; and to the positive electrodes (plates) on charge.

223−1.2 BATTERY INSTALLATIONS

223−1.2.1 PURPOSE OF BATTERIES IN SUBMARINES. The purpose of the main storage battery installation in a submarine is to furnish power for vital loads and other power-consuming equipment when the submarine is operating under conditions where the diesel engines or nuclear reactor cannot be used to supply power. The battery installation stores energy obtained from fuel combustion or nuclear reaction and delivers this energy as required. With existing batteries, the maximum energy stored is about 15 watt-hours per kilogram (7 watt-hours per pound) of battery. The maximum power capability is generally taken to be the 1-hour rate (explained in paragraph 223−3.5.3). This is 11 to 16 watts per kilogram (five to 7.5 watts per pound), depending on the cell design. In past diesel-electric submarines, the battery was the primary source of electrical energy when the submarine was submerged, and a secondary source when the submarine was on the surface or snorkeling. In nuclear submarines, the battery is a secondary energy source to backup the power plant. The focus of this chapter will be on nuclear submarines, except for particular notation regarding USS DOLPHIN.

223−1.3 CLASSIFICATION

Lead-acid submarine batteries are classified according to the alloy used in the plate grids. The lead-antimony alloy (grade LA) is used in diesel-electric submarine batteries, specifically USS DOLPHIN. The lead-calcium alloy (grade LC) is used in nuclear submarine batteries. A GUPPY I Mod C cell, GUPPY I Mod E cell, and TRIDENT cell are shown in Figure 223−1.

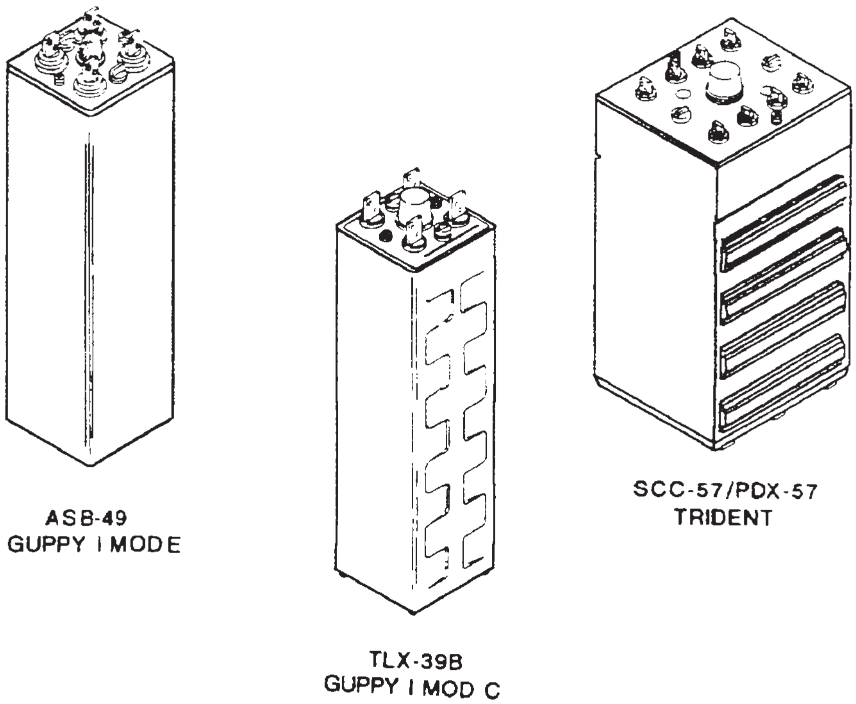


Figure 223-1. Submarine Main Storage Battery Cells

223-1.3.1 LEAD-ANTIMONY BATTERY TYPES AND INSTALLATIONS. The plate grid of a lead-antimony battery is composed of lead, alloyed with a small percentage of antimony. This kind of battery, especially suitable for deep cycling, is used in USS DOLPHIN battery installation consisting of two batteries of 126 cells each.

223-1.3.2 LEAD-CALCIUM BATTERY TYPES AND INSTALLATIONS. Lead-calcium battery types are used in nuclear submarines only and contain 126 (128 for TRIDENT) cells permanently connected in series. The positive plate grid is made of lead, alloyed with up to 0.085 percent calcium. This alloy makes a harder grid than pure lead. The negative plate grid is of the same alloy. Since nuclear submarines spend extended periods submerged, lead-calcium batteries are used in place of lead antimony batteries which emit stibine and arsine when charged. Lead calcium cells contain no antimony or arsenic and evolve no stibine or arsine. Lead-calcium batteries are described below:

a. GUPPY I Mod C (LC) Cell: The GUPPY I Mod C main storage battery is designed to be used as an emergency battery in nuclear submarines. It is the third of a series of GUPPY type batteries that have been designed for the Navy. This design of battery incorporates thicker plates, hence the increase in battery life. This battery contains 126 cells in its configuration.

b. GUPPY I Mod E (LC) Cell: The GUPPY I Mod E main storage battery is an advanced model battery and is used in a similar manner to the Mod C battery. Mod E characteristics are similar to those of the Mod C battery and have the same dimensions for interchangeability. The Mod E is heavier than the Mod C and also contains 126 cells in its configuration. The Mod E battery, however, provides up to 70 percent more energy at existing shipboard loads.

c. TRIDENT (LC) Cell: This cell is designed for use in a 128-cell battery in the TRIDENT Class submarines. This battery is essentially identical to the Mod C regarding design technology, but is physically larger with a higher ampere-hour rating.

223−1.4 CELL AND BATTERY DEFINITIONS

223−1.4.1 POSITIVE GROUP. The assembly of all positive plates having a common connecting busbar and terminal posts forms the positive group. The active material in submarine battery positive plates is lead dioxide. Flat positive plates consist of a lead-alloy grid into which the active material is pressed.

223−1.4.2 NEGATIVE GROUP. The assembly of all negative plates fused to a common connecting busbar and terminal posts forms the negative group. Negative plates consist of lead-alloy grids into which the active material is pressed. The negative active material is sponge lead. Sponge lead is lead reduced from lead-oxide and to which several ingredients have been added to help retain the porosity of the material over the life of the battery. These ingredients are usually lampblack, barium sulfate and certain organic substances.

223−1.4.3 SEPARATORS. Separators are microporous rubber insulators used to separate plates of opposite polarities. Separators are freely permeable to the electrolyte but have no openings that would permit trees of active material to bridge between the plates and cause an internal short circuit. Separators are grooved on the side facing the positive plate.

223−1.4.4 RETAINERS. Retainers are glass mats that serve to prevent shedding of positive active material while allowing access of electrolyte to the positive plate. It should be noted that retainers do not serve as separators, since it is possible for trees to form through the retainer thereby short circuiting the plates.

223−1.4.5 BINDING STRIPS. Binding strips are plastic, U-shaped insulators placed along each vertical edge of the positive or negative plates, or both, to prevent moss-type short circuits.

223−1.4.6 ELEMENT. An element is a complete assembly consisting of the positive and negative groups mounted together with separators and retainers in place, ready for installation in the jar liner.

223−1.4.7 ELECTROLYTE. The electrolyte consists of pure sulfuric acid diluted with pure water. The authorized full-charge specific gravity for the battery is contained in the manufacturer's service manual.

223−1.4.8 CELL LINER. A thin wall dielectric container made of cross-linked polyethylene in which the cell element (cell pack) is placed prior to insertion of the entire assembly into the cell jar. It retains the electrolyte and serves as protection against leakage, in case of cracks in the jar. The cover-to-liner seal provides for cell leakage integrity.

223−1.4.9 JARS. The element, liner and electrolyte are contained in a jar made of high-impact-resisting plastic or glass/epoxy composite.

223−1.4.10 COVERS. The jar is closed with a cover made of the same material as the jar and having openings suitable for watering and ventilating the cell. The cover is sealed to the liner using an asphaltic-type sealing compound with good adherence to the cover material, yet soft enough to withstand jar movement, relative to the cover, without cracking.

223−1.4.11 CELL. A cell is an element installed in a jar, with the cover in place. The cell may be dry, with dry plates and separators, or it may be filled with electrolyte.

223−1.4.12 BATTERY. A battery is a group of cells that are connected in series. A submarine having one group of cells consisting of 126 cells connected in series is said to have one battery of 126 cells. USS DOLPHIN has a configuration of two batteries of 126 cells each. Curves and data plans are always based on the (”as installed”) number of cells connected in series.

223−1.4.13 AMPERE-HOUR (AH). An Ah is the quantity of electricity delivered in one hour by a current with a value of one ampere (A). The Ah delivered by a battery on discharge is equal to the average current, in A, multiplied by the time of discharge, in hours.

223−1.4.14 SPECIFIC GRAVITY. Specific gravity is the ratio of the weight of any volume of a substance to the weight of an equal volume of some other substance taken as standard. The standard for liquids and solids is pure water. The specific gravity of any substance depends upon the temperature of the substance and the temperature of the standard with which its weight is compared. For an accurate specification of specific gravity, both temperatures must be given. An electrolyte specific gravity, for example, of 1.250 26.7° C/15.5° C (80° F/60° F) means that any volume of electrolyte at a temperature of 26.7° C (80° F) weighs 1.250 times as much as an equal volume of pure water at a temperature of 15.5° C (60° F).

NOTE

> Since characteristics of batteries in present use are still based on 80° F and 60° F, the British unit of temperature is retained as controlling the conversion factor for specific gravity.

223−1.4.15 NATO DEFINITIONS. The NATO Standardization Agreement (STANAG) number 4389 identifies the terms and definitions covering submarine main lead acid batteries as agreed upon by the Military Agency for Standardization (MAS). Additional information and inquiries concerning NATO agreements should be directed to NAVSEA Code 56Z14.

In addition to those terms defined in STANAG 4389, STANAG 4390 provides the MAS agreements for submarine main lead-acid battery tests and requirements.

223−1.5 BATTERY EFFICIENCY, REACTIONS AND PHENOMENA

223−1.5.1 EFFICIENCY. The electrical energy, in kilowatt-hours, that must be supplied to charge a battery from the completely discharged to the fully charged condition is always greater than the energy the battery will supply on discharge. Similarly, the quantity of electricity, in ampere-hours (Ah), that must be passed through a battery to charge it from the completely discharged to the fully charged condition, is always greater than the number of Ah the battery can supply on discharge. Input is greater than output. Because of several limiting factors, the energy efficiency of a lead acid cell is normally about 75 percent and the Ah efficiency is nominally 90 percent.

1. On charge, the current that can be effectively used to charge the battery decreases as the cell approaches the fully charged condition. To restore the fully charged condition without excessively prolonging the charge time, the battery must be charged at a rate that produces gas in addition to converting inactive material to active. Thus, inefficiency is introduced into the charge process.

2. The battery air agitator system promotes mixing of the electrolyte not normally achieved through normal or gassing charges. This feature enhances the efficiency of the cells by preventing electrolyte stratification.

223−1.5.2 CHEMICAL REACTION. The reversible chemical reactions that occur on charge and discharge are shown by the following equation:

NOTE

> The calculations shown in the charge/discharge equation are grams of reactants and products for a quantity of electricity equal to one Ah.

a. On discharge, lead is converted to lead sulfate at the negative plate, lead dioxide is converted to lead sulfate at the positive plate, and sulfuric acid is converted to water. Both the positive and negative plates increase in mass, though not by the same amounts, and the specific gravity (paragraph 223−1.4.14) of the electrolyte decreases. On charge, the reaction is reversed, storing electrical energy from the resulting chemical reactions.

b. The masses of the reactants converted and products formed for one ampere-hour passing through a perfect battery in either the discharging direction or charging direction are shown in grams below the equation. For an actual battery, however, it is found that the proportions given are accurate only when side reactions are absent.

Negative plate		Positive plate		Electrolyte liquid		Both plates		Electrolyte liquid
(-)		(+)				(-/+)		
Pb	+	PbO_2	+	2 H_2SO_4	On Discharge → yields ← On Charge	2 $PbSO_4$	+	2 H_2O
3.86 g/Ah		4.46 g/Ah		3.66 g/Ah		11.31 g/Ah		0.67 g/Ah

This is generally true on discharge when the electrolyte is pure and the cell is free from internal short circuits. Hence, the masses of the reactants converted and the products formed for a theoretically perfect cell serve as a reliable guide to the extent of discharge.

223−1.5.3 BATTERY PHENOMENA ON CHARGE AND DISCHARGE. The chemical reactions considered in paragraph 223−1.5.2 account for the conversion of chemical to electrical energy on discharge, and of electrical to chemical energy on charge. They do not, however, completely describe the behavior of the battery on charge and discharge since they are accompanied by a number of phenomena that affect battery operation and life. Among the most important of these phenomena are:

a. Change in plate volume

b. Gas evolution

c. Heat evolution

d. Electrolyte height changes.

223−1.5.3.1 Change in Plate Volume During Discharge. On discharge (paragraphs 223−1.5.2 and 223−1.5.3), lead is converted to lead sulfate at the negative plates and lead dioxide is converted to lead sulfate at the positive plates. These conversions result in a gain in mass of both plates. The lead sulfate is less dense than either lead or lead oxide, so the percent increase in volume of the materials is greater than the percent increase in mass. For moderate discharges, no apparent increase in plate volume occurs. Materials expand into the voids or pores, as has been proven by porosity measurements on charged or discharged plates. The normal result is a clogging of the pores. However, if discharges are prolonged beyond the limits described in paragraph 223−3.5.4, excessive expansion may take place with the result that the plate may actually bulge. Prolonged discharges thus promote shedding and may cause cracking of positive grid members strained by the expansion of the material held in the grid sections. To minimize these undesirable effects, care should be taken to avoid discharging any cell beyond the low voltage limit (Figure 223−2 and paragraph 223−3.5.4). Under emergency conditions the Commanding Officer may authorize the continued discharge below the low voltage limit.

223−1.5.3.2 Change in Plate Volume During Charge. On charge, lead sulfate is converted to lead at the negative plates and to lead dioxide at the positive plates, resulting in a reduction in mass and volume and a gain in plate porosity. When the conversion is substantially, although not entirely, complete gas begins to evolve from the plates. Excessive prolongation of charge, after gassing has started, results in shrinkage of the negative sponge lead. That is, the sponge hardens and tends to shrink away from the grids. Cracks appear in the sponge and, in severe cases, between the sponge and the grid members. To minimize this effect, overcharging should be limited to the amount required by charging instructions.

223−1.5.3.3 Gas Evolution. The following paragraphs concern gases and liquids evolved in a lead acid storage battery during the states of charging, discharging, stand and after salting.

a. Hydrogen and Oxygen: Hydrogen and oxygen are the main gases evolved from a lead acid storage battery during charge. Hydrogen is evolved at the negative plates and oxygen at the positive plates as a result of electrolysis of water in the electrolyte. Oxygen is normally the first gas evolved; some time later, the negative plate begins to gas. As a result, the initial gas evolved from a cell is practically pure oxygen; as the

TIME HRS	SERVICE ⊕		FINAL VOLTAGE AT BATTERY TERMINALS (As shown on final volts curve)	DISCHARGE CHARACTERISTICS																					
	1.285 SP. GR.			⊖ AVER FINAL CELL VOLTS	⊖ MIN. FINAL CELL VOLTS	EFFICIENCY		CAPACITY AT DIFFERENT INITIAL TEMPERATURES ⊗																	
						Ah	WATT-HRS	50°F		60°F		70°F		80°F		90°F		100°F		110°F		120°F		130°F	
	AMPS	kW	VOLTS					Hr	Min	Hr	Min	Hr	Min	Hr	Min	Hr	Min	Hr	Min	Hr	Min	Hr	Min	Hr	Min
1/2	6100	1156.0	160	1.31	1.05	90%	57%	—	24	—	26	—	28	—	30	—	31	—	32	—	33	—	34	—	35
1	4000	830.0	180	1.46	1.28	90%	68.5%	—	51	—	54	—	57	1	00	1	02	1	04	1	05	1	06	1	08
3	1750	399.0	201	1.61	1.51	90%	75%	2	38	2	46	2	53	3	00	3	05	3	08	3	11	3	13	3	16
5	1185	279.6	207	1.65	1.57	90%	76%	4	31	4	41	4	52	5	00	5	06	5	10	5	14	5	18	5	21
6	1025	243.9	208	1.66	1.58	90%	76.5%	5	24	5	38	5	50	6	00	6	08	6	13	6	17	6	21	6	25
10	680	163.8	212	1.69	1.63	90%	77.5%	9	16	9	30	9	46	10	00	10	10	10	17	10	23	10	26	10	30
20	370	90.2	215	1.71	1.66	90%	78.5%	18	42	19	14	19	40	20	00	20	12	20	20	20	28	20	34	20	37
36	215	52.8	217	1.72	1.68	90%	79%	34	12	34	58	35	34	36	00	36	14	36	24	36	32	36	39	36	39
48	165	40.7	217	1.72	1.68	90%	79.5%	45	51	46	48	47	31	48	00	48	12	48	20	48	26	48	31	48	31

NOTES:

1. On account of variation of gassing, in respect to voltage, all charging should be conducted as set forth in battery instructions.
2. Battery voltage discharge curves are based on voltages at terminals of each 126–cell battery unit and includes loss in the intercell connectors on the basis of 0.843% drop at the 3–hour rate in 1.285 sp. gr.
3. The voltage curves should not be applied as a limiting feature for individual cells. See average and minimum final cell volts in table of discharge characteristics above.
4. Capacity based on initial electrolyte temperature of 80°F.
5. Discharge curves are based on service capacity.

⊕ Capacity within 30 cycles

⊗ Based on air temperatures remaining constant at initial temperature of electrolyte

⊖ At cell terminals

CELL DATA

Cell height inclusive of terminal posts, not to exceed 55.250 inches.
Outside width, not to exceed 14.224". Length not to exceed 14.224".
Jar inside depth, not less than 49.145". Width, not less than 12.850. Length, not less than 12.658".
Positive plate, tlx type, height at center, not less than 39.0". Width, not less than 11.81". Thickness, not less than 0.195.
Negative plate, tlx type,, height at center, not less than 39.0". Width, not less than 11.81". Thickness, not less than 0.142.
Separators–ribbed, porous, hard rubber compound and glass mat retainer.
Total thickness of separators, not less than 0.145".
Plate centers, like polarity, 0.650" nominal.
Sediment space 2" nominal. Normal height of electrolyte above negative plates 4.87".
Weight of complete cell charged –1.285 sp. gr. of electrolyte not to exceed 1086 lbs. maximum average.
Individual cell not to exceed 1107 lbs.
Weight of electrolyte –nominal weight of electrolyte for filling cell containing dry plates and separators, fully charged – sp. gr. 1.285.
Use 210 lbs., 1.255 sp. gr. pouring acid.
18.5 gallons of electrolyte required to fill cell with dry separators.
Operating range based upon 1.285 sp. gr. (1.275–1.295) sp. gr. fully charged

HEIGHT OF ELECTROLYTE

The operating specific gravity is based on electrolyte at normal level which is 5–1/2 inches below the top of the service opening.

Figure 223−2. Typical Data Sheet

charge progresses, the ratio of hydrogen to oxygen increases and finally becomes two to one. The gas evolved during discharge and stand is mainly hydrogen, which is evolved as a consequence of chemical self-discharge (paragraph 223−6.2.3). Hydrogen accumulation is a constant, severe hazard (paragraph 223−4.1.2).

b. Stibine: Lead-calcium grid batteries contain no antimony. Thus, there is no evolution of stibine gas, even for prolonged submerged operation. USS DOLPHIN however uses a lead-antimony grid battery; this battery emits small quantities of stibine, an unstable highly toxic gaseous compound of antimony and hydrogen. This gas is evolved when the cell is being charged at a potential above approximately 2.45 volts. The amount evolved appears to increase with the charge voltage and the cell temperature. Old cells with bad negative plates that cannot be brought up above 2.45 volts at normal finishing rates do not evolve appreciable quantities of stibine. New cells with healthy negative plates which have a charge voltage in excess of 2.60, evolve the maximum amount of stibine.

c. Arsine: Lead-calcium grid batteries contain no arsenic. Thus, arsine gas evolution is nonexistent. The USS DOLPHIN battery uses a lead-antimony grid which may contain a small amount of arsenic. Arsenic produces a gaseous compound of arsenic and hydrogen having toxic properties similar to stibine. However, the extremely small quantities of arsenic permitted in lead-antimony grid cells make it improbable that arsine will be present unless arsenic has been added to the cell in violation of specifications for grid alloys, active material, water and electrolyte.

d. Chlorine: Chlorine will be evolved any time a battery is salted (i.e., contaminated with seawater) whether the battery is on charge, discharge or stand (paragraph 223−6.5.2).

e. Acid spray: Also present in the battery gas are small quantities of acid spray, which produce a highly corrosive atmosphere and extremely small quantities of sulfur compounds derived from the rubber separators.

223−1.5.3.4 Heat Production. There are three principal sources of heat in the battery: heat produced by the electrical resistance of the electrolyte, plates and cell connectors; heat produced by the formation of molecular hydrogen and oxygen during the gassing phase of charge; and heat produced by the chemical reactions occurring in the cell.

a. Electrical Resistance: The electrical resistance of the battery creates heat during both charge and discharge. The rate at which heat is produced is equal to the product of the internal resistance and the square of the current of the battery, and is appreciable only at high rates of charge or discharge. As a rule, no appreciable temperature rise is observed on discharge when the current is lower than the 6-hour rate. At the 1-hour rate, however, a temperature rise of 17 to 22° Celsius (C) (30 to 40° Fahrenheit (F)) may result if the rate is maintained for one hour.

b. Gas Formation: In normal operation, the principal source of heat during charge is the heat of formation of molecular hydrogen and oxygen during the gassing phase of charge. Temperature rise during charge is usually small until the battery starts gassing, after which a much greater rise occurs.

c. Chemical Reaction: The chemical reactions occurring in a cell absorb heat from the surroundings on discharge and produce heat on charge. The magnitude of this effect is proportional to the current. This effect, combined with the other sources of heat, results in a greater temperature rise during charge than during discharge at the same current.

223−1.5.3.5 Harmful Effects of High Temperature. The harmful effects of high temperature are as follows:

a. Self-discharge and Hydrogen Evolution: High temperature is particularly harmful in that self-discharge on stand and hydrogen evolution on stand or discharge increase rapidly as the temperature rises. If a ship were submerged and no hydrogen burning or scrubbing were taking place, a battery may permit submerged operation for 48 hours at 26.7° C (80° F) before the hydrogen content in the ship reaches three percent. However, the same battery may permit only 24 hours of submerged operation at a temperature of 37.8° F (100° F) and only about 12 hours of operation at 48.9° C (120° F).

b. Positive and Negative Plate Damage: High temperatures promote sulfation of negative plates and also provide favorable conditions for deposit of sediment on plates, which may result in trees of active material between plates of opposite polarities. This is called a moss short circuit. High temperature also accelerates corrosion of positive grid members and, therefore, reduces grid life.

c. Water Loss: High temperatures greatly increase water loss from cells, increasing the watering burden. Where water contains small amounts of impurities, increased frequency of watering caused by high temperatures may be a factor in reducing battery life.

223−1.5.3.6 Electrolyte Height Changes. The initial electrolyte level of a newly-filled cell will decrease as the electrolyte soaks into the pores of the active material (paragraph 223−2.10.1). The electrolyte level of any cell must never be allowed to fall below the level specified in the applicable battery service manual. The applicable height correction procedure is explained in paragraph 223−5.3.3.1.

a. Gassing in all Cells: In all lead-acid batteries, electrolyte height increases are caused by the displacement of the electrolyte from pores in the active material by gases produced during use (paragraph 223−1.5.3.3). These gases will gradually leave the pores of the plates and rise to the surface during stand. In the lead-calcium cell, due to the low self-discharge rate, very little gas is formed within the pores of the plate and the total gas volume decreases as the cell stands on open circuit or during prolonged low-rate discharges.

b. Water Loss in Lead-Calcium Cells: Water losses are much lower in lead-calcium cells than in lead-antimony cells because the lead-calcium cells are normally operated below the gassing voltage. For this reason, the electrolyte level decreases slowly and very little makeup water is required.

USS DOPLHIN: (lead-antimony cells) Water losses are considerably greater with a corresponding decrease in electrolyte level. Specific gravity readings taken prior to watering cells must be corrected to give the readings as they would appear if the electrolyte were at the normal level. The height correction procedure is explained in USS DOLPHIN Main Storage Battery Technical Manual.

223−1.5.4 DETERMINING CHARGE STATE FROM SPECIFIC GRAVITY. Since the mass of the plates and the specific gravity of the electrolyte depend upon the quantity of electricity passing through a battery, its state of charge at any time can be determined by measuring the mass of either a positive or negative plate or plates, or the sulfuric acid in the electrolyte. Comparison of any one of these masses with the corresponding mass for a fully charged cell would furnish a measure of the amount the cell has discharged. It is impossible, however, to measure the mass of the plates in a cell being used without destroying the cell. Instead, the mass of acid can be determined quite readily by measuring the specific gravity of the electrolyte and applying certain necessary corrections. This is the reason for the extensive use of specific gravity measurements in connection with the operation and care of lead acid storage batteries.

223−1.5.5 RELATION BETWEEN AH AND DROP IN SPECIFIC GRAVITY. As explained in paragraph 223−1.5.2, 3.66 grams (0.129 ounces) of sulfuric acid are used up per Ah (paragraph 223−1.4.13) of discharge through the battery. Tables on the density of sulfuric acid solutions show that a drop in specific gravity (paragraph 223−1.4.14) at 26.7° C (80° F) of 0.001 (one point) corresponds to a decrease in acid content of 1.7185 grams per liter (0.229 ounces per gallon). Hence, if the volume of electrolyte is one liter, a drop in specific gravity of 0.001 corresponds to 1.7185/3.66 = 0.4696 Ah (and for one gallon, 0.229/0.129 = 1.775 Ah) passing through the cell. Consequently, for any cell, the Ah per point (Ah/pt) drop in specific gravity is 0.4696 times the number of liters (1.775 times the number of gallons) of electrolyte. For the battery types now in use, the theoretical values of the Ah/pt are as shown in Table 223−1. The observed value of Ah/pt drop on discharge is usually greater than the theoretical value. This is because specific gravity decreases faster in the electrolyte next to the plates than in the electrolyte above the plates. The observed specific gravity drop is based on measurement of the specific gravity of electrolyte drawn from above the plates. Consequently, observed specific gravity drop during discharge is less than the true or average value for the entire electrolyte. For hourly rates equal to or longer than the 20-hour rate (paragraph 223−3.5.3), the difference is negligible. For the 10-hour rate, the difference is about five percent. For the 1-hour rate, however, the difference may be 50 percent, so that the Ah per observed specific gravity drop are twice the theoretical. (see paragraph 223−3.5.13.3 for output calculation).

223−1.6 CURVES AND DATA CHARACTERISTICS

Characteristic curves and data are shown for each type battery in the applicable manufacturer's service manual. A typical data sheet is shown in Figure 223−2; typical characteristic curves in Figure 223−3. Typical dimensions, weight, current and power ratings, cycle life and calendar life guarantees, and manufacturer's designation are shown in Table 223−2.

223−1.7 BATTERY CONNECTIONS

The battery forms part of the propulsion system of the submarine in which it is installed. Tapping a battery between cells increases the drain on a portion of the bat-

Table 223−1. AMPERE-HOUR PER POINT DROP IN SPECIFIC GRAVITY

Type	3-Hour rate Ah/pt	10-Hour rate Ah/pt
GUPPY I MOD C (LC)	43	33
GUPPY I MOD E (LC)	49	37
TRIDENT I (LC)	91	66

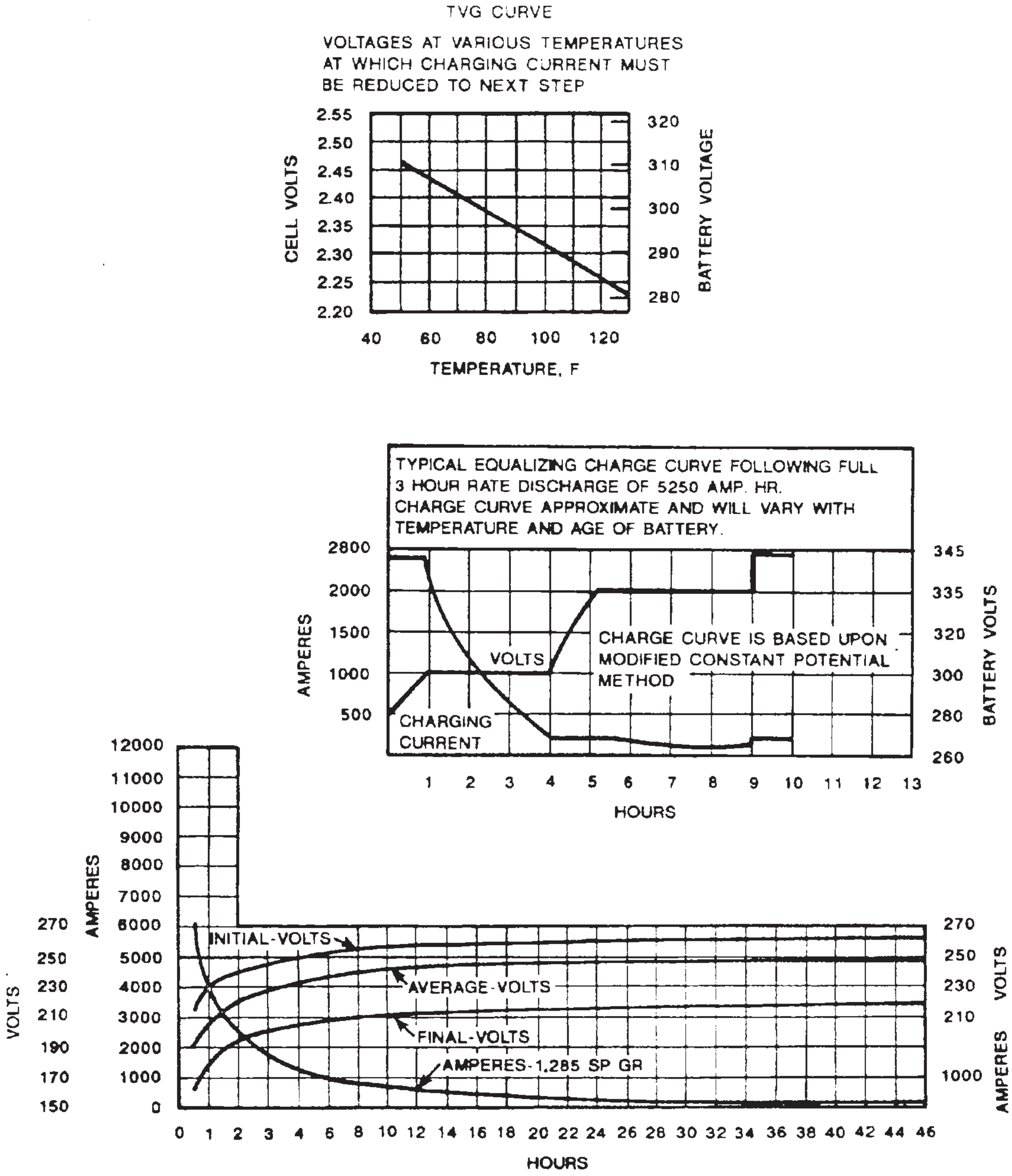


Figure 223−3. Typical Battery Characteristic Curve

Table 223−2. SUBMARINE BATTERY CHARACTERISTICS

Items	Lead antimony	Lead calcium		
Navy designation	**DOLPHIN**	**GUPPY 1 Mod C (LC)**	**GUPPY 1 Mod E (LC)**	**TRIDENT 1 (LC)**
Manufacturer				
Designation				
GNB	DSB-45B	TLX-39B	ASB-49	PDX-57
C&D				SCC-57
Mil specs		24541/2	24541/5	24541/3
Cells per submarine	2 x 126	126	126	128
Guarantee				
Months	36	66	66	72
Cycles	275	165	165	200
Charge amp-hours per equivalent cycle	2400	5000	6500	10,000
Dimensions (mm)				
Width	331	360	361	513
Length	261	360	361	592
Height	657	1400	1400	1176
Weight per cell (Kg)				
Average	154	469	594	953
Maximum	158	497	606	1043
Electrolyte specific gravity	1.285	1.285	1.295	1.285
Electrical characteristics				
1-Hour rate				
Current (A)	1725	4000	5400	7500
Capacity (Ah)	1725	4000	5400	7500
Power (kW/cell)	3.09	6.59	8.67	12.36
3-Hour rate				
Current (A)	740	1750	2400	3450
Capacity (Ah)	2220	5250	7200	10,350
Power (kW/cell)	1.40	3.17	4.46	6.25
6-Hour rate				
Current (A)	425	1025	1350	2025
Capacity (Ah)	2550	6150	8100	12,150
Power (kW/cell)	0.83	1.94	2.59	3.83
10-Hour rate				
Current (A)	270	680	875	1340
Capacity (Ah)	2700	6800	8750	13,400
Power (kW/cell)	0.53	1.30	1.70	2.56

tery. Study the wiring diagrams to determine the effect of any battery taps. Consult power plant instruction books for battery connections and circuit schematics pertaining to a particular submarine.

223−1.8 SUBMARINE ELECTRIC PROPULSION SYSTEMS

In general, submarine electric propulsion systems are classified as a single-bus system. The system voltage, the number of generators and motors included in the system, and the number and type of batteries installed will vary according to the particular installation. For a detailed description of any particular system, the applicable instruction books should be consulted.

223−1.8.1 SINGLE-BUS SYSTEM. In the single-bus system, the battery, generators and motors are all connected to the same propulsion bus. When operating submerged, the battery and motors are connected to the bus, and ship speed control is accomplished by the use of motor armature setups and motor field control. When operating while surfaced or snorkeling, the generators are also connected to the propulsion bus and ship speed is controlled in the same manner. When operating while surfaced or snorkeling, the battery may be either charged or on trickle-discharge. The amount of power available for propulsion and the generator voltage when in this operating condition, are dependent upon the battery voltage, the rate at which the battery is being charged and the amount of auxiliary power being furnished.

223−1.9 ACCESSORY EQUIPMENT AND AUXILIARY SYSTEMS

Accessory equipment provided for submarine storage batteries to permit safe and efficient operation includes:

a. Voltmeter (battery and individual cell)
b. Ammeters
c. Ampere-hour meters
d. Battery ventilation system
e. Battery airflow meters f.
f. Hydrogen detectors
g. Hydrogen burners
h. Hydrometers
i. Thermometers
j. Electrolyte level gauge
k. Indicating water fillers
l. Ion exchangers
m. Battery water conductivity tester
n. Flash arresters
o. Electrolyte agitation system
p. Ground resistance meters
q. Battery test kit
r. Insulated torque wrenches
s. Quick disconnects.

223−1.9.1 VOLTMETERS. Voltmeters are provided to measure battery voltage, individual cell voltage, and for a small number of submarine installations, voltage to ground for the determination of ground resistance. Consult the power plant instruction book for the location and function of the voltmeters installed in the submarine.

223−1.9.1.1 Battery Voltmeters. Nuclear submarines have a single voltmeter used for the battery.

223−1.9.1.2 Individual Cell Voltage (ICV) Meters. Submarine batteries have an individual cell voltage (ICV) panel.

The panel contains a meter, controls and jacks to permit measuring the voltage of each cell. The voltmeter can be manually connected to read the voltage of any cell or the battery by plugging into the jacks associated with the cell number on the panel or the positive and negative end jacks.

223−1.9.1.3 Ground Detector Voltmeters. Formerly, the resistance to ground had to be determined by measuring the voltage to ground. However, those ground detector voltmeters have been generally superseded by a device that indicates the resistance to ground directly in ohms as mentioned in paragraph 223−1.9.16.

223−1.9.2 AMMETERS. All installations have a battery ammeter. The amount of current through the battery on either charge or discharge is found by reading the battery's ammeter.

223−1.9.3 AMPERE-HOUR (AH) METER. All installations have a battery Ah meter for each battery. These meters are designed to register Ah input and output. Ampere-hour meters should be used to determine the Ah of discharge during routine operations. They should not be used as criteria for determining completion of charges unless specific instructions are issued by the Naval Sea Systems Command (NAVSEA). The procedure for using Ah meters is:

1. Ampere-hours of Charge: To read Ah of charge, set meter to read zero at start of charge. Subsequent readings up to end of charge will give Ah of charge.

2. Ampere-hours of Discharge: To read Ah of discharge, set meter to zero at end of each charge. Subsequent readings up to start of next charge will give Ah discharge.

3. Consult Ah meter instruction book for guidance on the accuracy of registration. Note that, at constant current, the ammeter reading multiplied by the time interval that current is maintained should equal the change in Ah meter reading. Thus, if the ammeter reads 300-A over an interval of three hours, the Ah meter reading should change by 900 Ah. Hence, the ammeter and the Ah meter can be used to check each other.

4. The Ah meter installed in nuclear submarines has a digital indicator that counts Ah during charge and discharge. The indicator should be reset to zero prior to each charge or discharge. The indicator counts in one direction only and will continue to add, whether the mode is charge or discharge. Therefore, it is necessary to record initial and final readings to determine quantity for each charge or discharge.

223−1.9.4 BATTERY VENTILATION SYSTEM. Battery ventilation is necessary to dilute the hydrogen evolved from lead acid cells.

a. Hydrogen concentration must be reduced at all locations outside the cells to less than three percent, a noncombustible concentration. The volume of air necessary to do this will also reduce the concentration of the other gases evolved to the point where the health of personnel is not affected. (See Section 4 for complete information.) A secondary effect of ventilation is battery cooling.

b. The ventilation system provides an even distribution of air entering through a plenum at one end of the tank and discharging through a plenum at the other end. In some tanks, fans are arranged to produce a swirl of air within the tank. These fans are termed recirculating fans. Each cell has an opening at the top, fitted with a flash arrester, through which the cell gases are vented.

c. In operation, the battery tank is ventilated by the ship's exhaust system, which draws fresh air into the battery tank from the compartment above. The cell gases diffuse through the flash arrester and mix with the airstream. The hydrogen air mixture is then drawn into the ship's exhaust system.

d. The hydrogen concentration at a location above the cells will depend in part on the air velocity at that point. The inlet and exhaust plenums (and the recirculating fans, if installed) are designed to make the airflow as uniform as possible. See Section 4 for complete information.

223−1.9.5 BATTERY AIRFLOW METERS. Submarine ventilation systems are equipped with airflow meters as follows:

a. Airflow meters are connected to the battery ventilation ductwork and measure the airflow through the duct. This quantity is the total volume of air passed through the battery and is, therefore, proportional to the average cell airflow. The meters only provide an indication of the airflow rate, the operator must verify if the degree of ventilation is safe or unsafe. Hence, every care should be taken to see that these meters are installed properly and checked regularly by qualified personnel as required by paragraph 223−5.5.2.

b. Each ship should have a set of calibration curves for the venturi airflow meters, plotting pressure versus airflow for each venturi. These curves make it possible to check the airflow reading on the airflow meter by connecting a suitable U-tube manometer across the venturi.

c. Gauging the amount of ventilation by fan speed is unreliable since the ventilation may be impaired by the improper closing or opening of valves or dampers without warning. Battery fan ammeter readings (if installed), because they merely indicate that current is flowing through the motors, would not necessarily reflect a casualty to or disruption in operation of the motor or the fan. They also would not indicate that the air duct is obstructed or that ventilation is satisfactory.

223−1.9.6 HYDROGEN DETECTORS. Hydrogen detectors are devices that indicate the concentration of hydrogen in the atmosphere at the location being sampled. The detector works on the principle that a hydrogen-air mixture produces greater cooling of a heated wire than a hydrogen-free atmosphere. The cooling effect is measured electrically on a meter calibrated in percent hydrogen. Devices using this effect are called thermal conductivity types.

a. A portable hydrogen detector, described as a portable indicator, or gas leak detector, is provided to determine the concentration of hydrogen in the ship's atmosphere. This device can be carried into any part of the ship to sample the local atmosphere.

b. All submarines have permanently installed hydrogen detector instruments. Either an Engelhard Industries instrument (Figure 223−4), or, in the case of TRIDENT Class, a Chrysler model SKEE 599, for each battery tank. These instruments are a thermal conductivity type of hydrogen detector, incorporating two independent indicators in one case. The sensing units are mounted within the battery exhaust ducts, and electrical connections are made to the control panel. The control panel contains meters to indicate percentage of hydrogen, and direct current (dc) voltmeters to measure bridge voltage. Two remote reading meters indicating the percentage of hydrogen are also provided.

c. The hydrogen detector reading gives the average hydrogen concentration in the battery ventilation system from which the unit draws its sample. In order to minimize the possibility of an incorrect reading on the hydrogen detector due to an erroneous set-

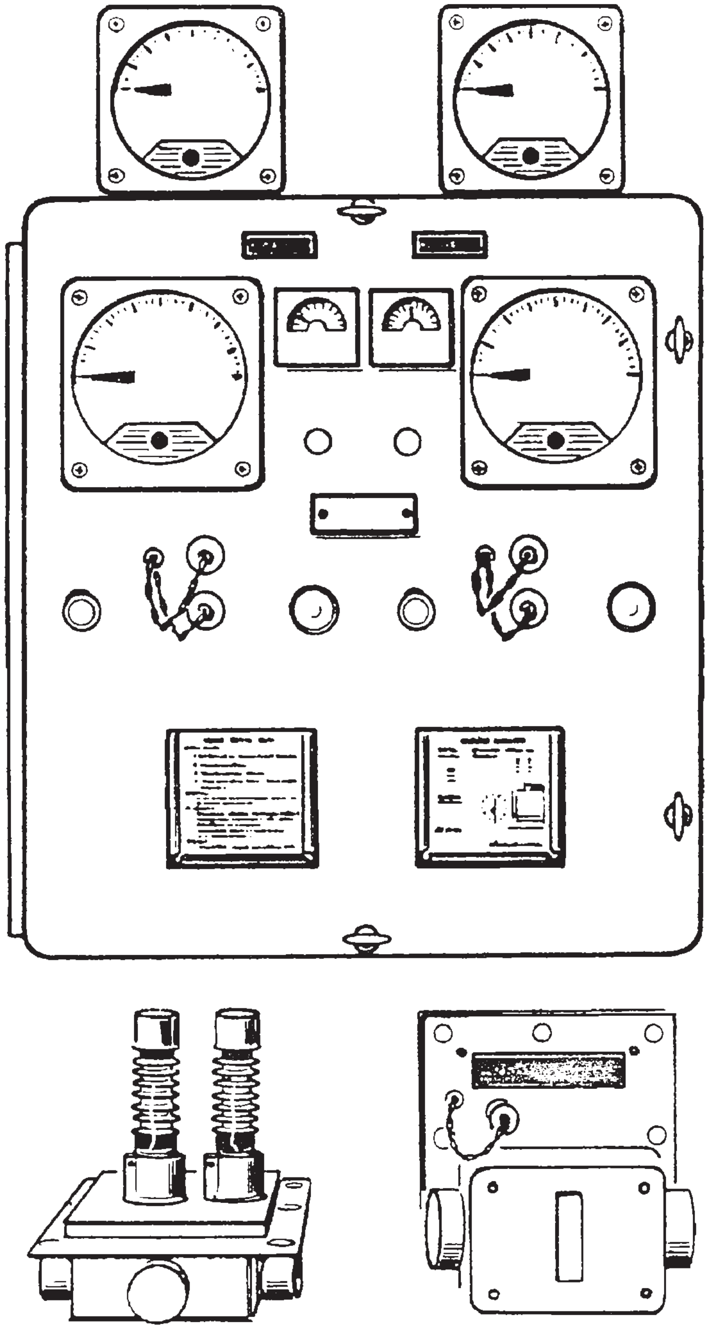


Figure 223−4. Hydrogen-gas Indicator

ting of bulkhead valves, the sampling point of each hydrogen detector shall be located upstream of the venturi of the airflow meter. See paragraph 223-4.1.4.6 for the relation of the average concentration to the highest concentration. The highest concentration at any point in the battery ventilation system forms the basis for taking precautions and making estimates of relative safety.

d. Instruction books are provided for portable hydrogen indicators and permanently installed hydrogen detectors. They should be thoroughly understood by personnel responsible for the use of these instruments.

223−1.9.7 HYDROGEN BURNERS. A hydrogen burner is a device that burns hydrogen efficiently even at concentrations in air below four percent. This is accomplished by means of a catalyst. Permanently-installed, hydrogen-carbon monoxide burners burn hydrogen that is evolved during charging operations while the submarine is submerged.

223−1.9.8 HYDROMETERS. A hydrometer is a device for measuring the specific gravity of a liquid (paragraph 223−1.4.14). It consists of a weighted bulb with a long stem. When the hydrometer floats in a liquid, the depth of immersion, over the range for which it is designed, decreases linearly with increasing specific gravity. The stem is graduated to show the specific gravity corresponding to each depth of immersion. (see Table 223−2 for hydrometers used with submarine batteries)

223−1.9.9 THERMOMETERS. Thermometers are used to measure the battery cell electrolyte temperature. Mercury-in-glass type thermometers are prohibited in submarines. The only thermometer allowed in submarines is the dial-type bimetallic thermometer (Table 223−3). These devices must be properly insulated with either a plastic or rubber coating to prevent accidental short circuits or sparks in the battery compartment.

223−1.9.10 ELECTROLYTE LEVEL GAUGE. To measure the height of electrolyte, an electrolyte level gauge, NSN 9G6680−00−246−1103, is furnished (Figure 223−5). The gauge tube is inserted into the cell filling opening until the crossbar rests on the top of the opening. The thumb is then placed over the open end of the tube to seal this end. The tube is then lifted vertically out of the cell. The height of the liquid column at the bottom of the tube, as shown on the marks at the side of the tube, is the height of electrolyte.

NOTE

> The plastic tube is sometimes provided with a spring-loaded plunger that retains the electrolyte within the tube after withdrawal.

223−1.9.11 INDICATING WATER FILLER. Each watering line in the battery tank is fitted with a special nozzle or filling gun that indicates when the normal level has been reached. After the filling gun is seated in the cell cover service cap opening, the valve is opened and flow maintained until the float indicator rises to the normal mark. The valve is then closed by releasing the handle. Various designs of indicating water fillers have been used, many of which are now in use. Filler design has now been standardized to one type of construction with two sizes available for use with the two major categories of batteries. The fillers are constructed of plastic and insulated, metallic parts. The standardized indicating water fillers are illustrated in Figure 223−6 and Figure 223−7.

Table 223–3. BATTERY TEST KIT

Equipment	National stock number	Onboard allowance
1. Barrel, syringe, Type A	9L6630-00-290-0500	6
2. Bulb, hydrometer (rubber)	9L6630-00-286-3868	4
3. Gauge, electrolyte level (8 points/inch or 1 point per 3 mm)	9G6680-00-246-1103	3
4. Gloves, rubber, size 10	9D8415-00-266-8677	8
5. Hose assembly	9C4720-00-230-6577	3
6. Hydrometer, graduate float (range 1.228 to 1.316)	1H6630-00-116-5599	6
7. Hydrometer, graduate float (range 1.200 to 1.280)	9L6630-00-580-3951	6
8. Hydrometer, graduate float (range 1.060 to 1.240)	1H6630-01-049-1009	6
9. Plug, bottom, hard	9L6630-00-291-8077	3
10. Plug, top, soft	9L6630-00-291-8081	3
11. Thermometer, dial, bimetallic	9G6685-00-802-9270	3
12. Restrictor, fluid flow	9C4730-00-203-7626	24
13. Teflon rod, 4.76 mm (3/16 in) diameter	9G9390-00-781-7851	2
14. Filler cap, battery vent dome	9GV6140-00-731-9144	2
15. Tube with collar (air supply tube)*	9GS6140-00-931-4656	126*
16. Battery record book	1HS0000-LL-CJ7-1082	1

*Depending on type of battery installed, this item is covered by the following Allowance Parts List (APLs):

090660030	(TLX39B)	GUPPY 1 MOD C (LC)
	(ASB-49)	GUPPY 1 MOD E (LC)
T09890002	(SCC57)	TRIDENT 1 (LC)
T090660036	(PDX57)	TRIDENT 1 (LC).

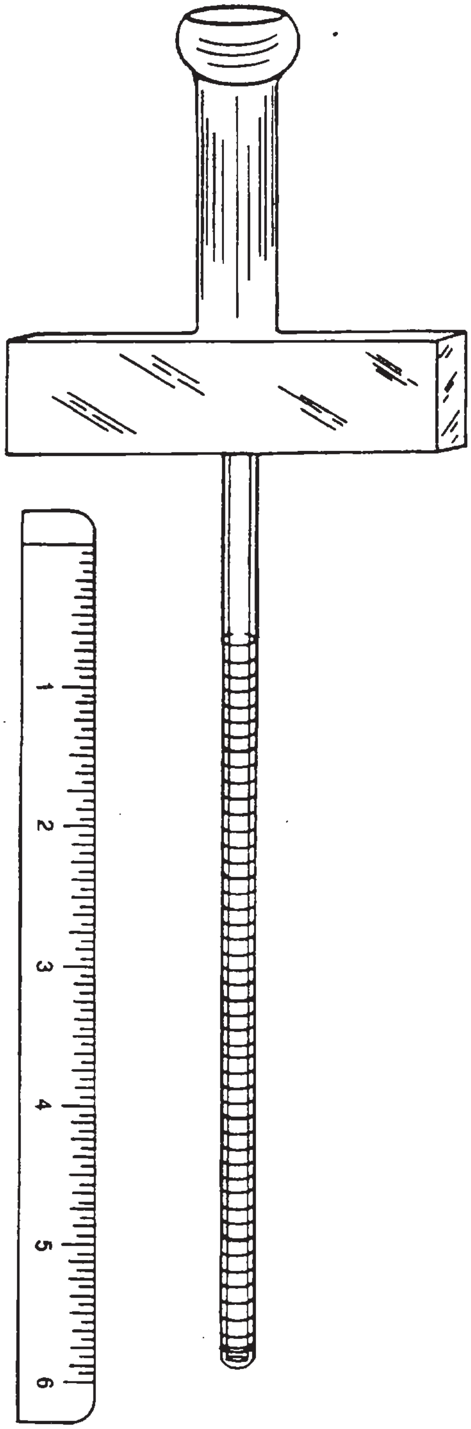


Figure 223−5. Electrolyte Level Gauge

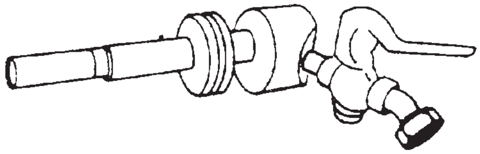


Figure 223−6. Indicating Water Filler A

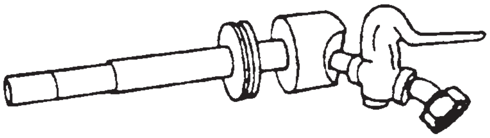


Figure 223−7. Indicating Water Filler B

NOTE

Water filler A, NSN 1H6140−00−032−4888, is used when the distance between the normal water level and the service tube opening is not more than 125 mm (five inches). Water filler B, NSN 1H6140−00−032−4889, is used when the distance between the normal water level and the service tube opening is greater than 125 mm (five inches).

223−1.9.12 ION EXCHANGERS. The ion exchangers used in submarine battery watering systems purify water by removing charged impurities dissolved in the water. The ion exchangers for battery filling water purification are in the form of a cylinder capped at each end (Figure 223−8). The cylinder holds about 10 liters (2.5 gallons) of resin. The resin is retained by a very fine screen made of multiporous hard rubber. In filling the cylinder, pack the resin firmly but not so tightly that excessive water pressure will be required to force water through the exchanger. If the flow rates are too low after installation, check the assembly. If the assembly is correct, the unit may be clogged. The ion exchanger in use is described in paragraph 223−1.9.12.1.

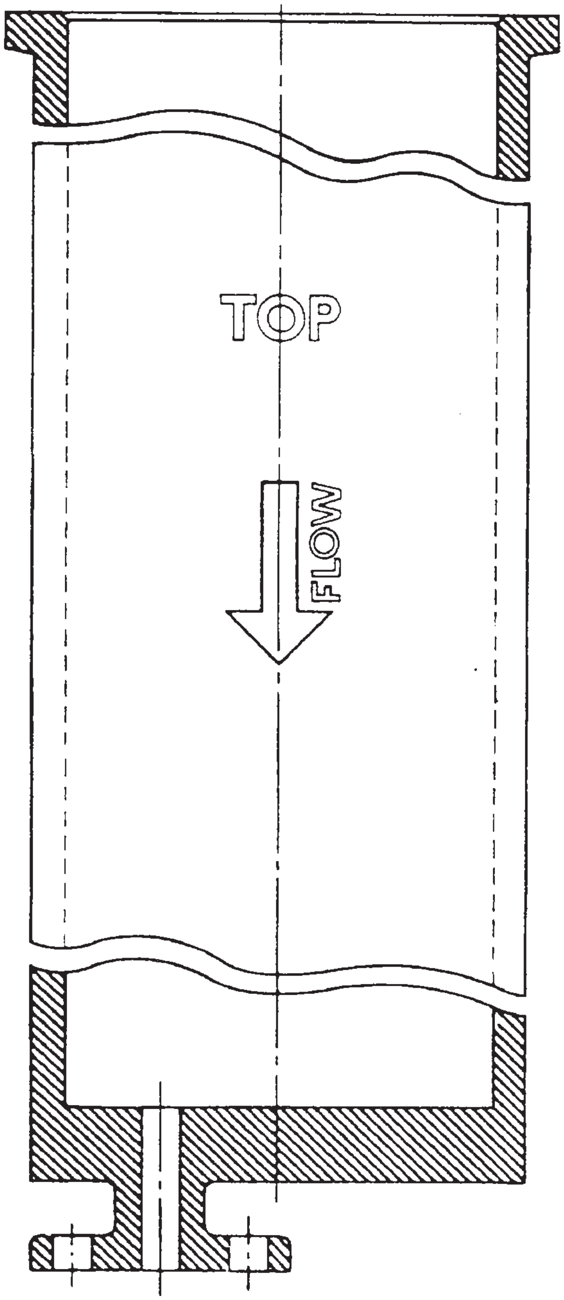


Figure 223−8. Ion Exchanger

223−1.9.12.1 Mixed-bed Exchanger. In purifying the battery cooling or make-up water, a mixed-bed type of ion exchange resin is used to combine with positive ions and liberate hydrogen ions. The resin also combines with negative ions and liberates hydroxyl ions. The hydrogen ions and the hydroxyl ions then combine to from water ($H^+ + OH^- \quad H_2O$). Therefore, under proper operating conditions, only pure water is discharged from the mixed-bed ion exchanger. The water will be very pure until the resin becomes saturated. Saturation will be indicated by a rise in salinity shown on the installed salinity meter. However, it is desirable to replace the material before saturation occurs. Under average operating conditions, the mixed-bed ion exchange resin should be replaced every 30 days. It is not practical to regenerate this material in the field. If a sharp rise in salinity is shown on the salinity meter before 30 days have elapsed, check to be sure that proper flow rate is being maintained. If proper flow rate is being maintained and the salinity becomes excessive (paragraph 223−5.2.1.1), replace the resin. The salinity should then drop to a very low value.

223−1.9.12.2 Installation of Mixed-bed Ion Exchange Unit. One mixed-bed ion exchanger is installed in the ship's demineralized (DI) water supply. This will permit about four to six liters (one to 1-1/2 gallons) per minute to be bypassed through the ion exchanger. Higher flow rates should not be used. The unit should be mounted vertically for downflow operation.

223−1.9.13 BATTERY WATER CONDUCTIVITY TESTERS. Water conductivity testers are being phased out as the current stock is depleted. The silver nitrate test (paragraph 223−5.3.2.1) is used instead.

223−1.9.14 FLASH ARRESTERS. Cells are equipped with porous domes through which the explosive gas generated in the cell is vented into the battery tank. These domes act as flash arresters. An external spark or flame on the outside of the dome will not be propagated back into the space beneath the dome (Figure 223−9). Tests made at the Naval Research Laboratory on a GUPPY cell disclosed that with a gassing current of 300 amperes, a spark produced at the surface of the dome did not produce an explosion either outside or inside the cell. At the same gassing current, but with a plastic housing surrounding the dome to raise the hydrogen concentration outside the dome to eight percent, a spark on the outside of the dome but within the housing caused an explosion. The housing bellied out and then returned to its original shape. There was no evidence of flash-back into the cell. The second test was repeated using an electrically-ignited squib in lieu of a spark. The squib produced a flash and a large quantity of heat and smoke. Again, the gas within the housing exploded but no damage was done to the cell. The second test was repeated using a charging rate of 600 amperes. Although the hydrogen in the cell exploded, damaging the cover and jar, later tests have shown that the explosion observed in the test at 600 amperes was due to an imperfect seal between the dome and the cell cover. With a good seal, the dome will handle a 600-ampere charging rate without difficulty.

223−1.9.14.1 Flash Arrester Seal. Flash arresters have an O-ring gasket to seal the assembly to the cell cover. It is important to keep in mind that the effectiveness of the dome depends on its being the only path for explosive gas to leave the cell. Any bypass will reduce the value of the dome; any crack in the dome will reduce its effectiveness.

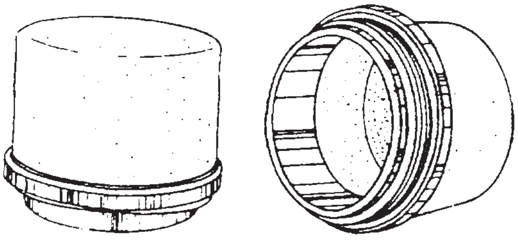


Figure 223−9. Flash Arrester

223−1.9.15 ELECTROLYTE AGITATION SYSTEM. Acid formed during charge (paragraph 223−1.5.2) is denser than the electrolyte in a partly charged cell. It descends and tends to produce much higher densities at the bottom of the cell than at the top.

a. The agitator counteracts this settling effect by pumping the electrolyte below the plates up to the top of the plates. Because of this, less gassing charge is needed to mix the electrolyte. Electrolyte agitation is critical for lead-calcium batteries because they are not subjected to a prolonged overcharge that, by causing vigorous gassing, helps electrolyte mixing.

b. Secondary but important benefits of the agitation system is that it tends to equalize electrolyte temperature from top to bottom within the cell and dilutes or purges hydrogen above the electrolyte. Equal temperatures and specific gravities throughout a cell will enhance equal working of plates along their height, reduce the net rate of positive grid corrosion and extend service life. For these reasons the agitation system is operated continuously for all battery types.

c. Each cell is equipped with an airlift pump (TRIDENT cells have two each) whose construction is shown in Figure 223−10. The air supply for the airlift pump is furnished by an air distribution system that distributes air to each cell airlift pump and is connected by a clear plastic hose. The quantity of air supplied is about 850 cubic centimeters per minute (cm^3/min) or 0.03 cubic feet per minute (ft^3/min) per airlift pump, as indicated on the rotameter in the supply line. The distribution system is self-equalizing by a throttling orifice placed at the air supply header in the hose connection to each cell. Minor leaks and blockages may seriously unbalance the system. The pumping rate of the airlift pump is reasonably uniform despite considerable variation in airflow. The electrolyte level has a major effect on controlling the pumping rate. The lower the level below the airlift pump discharge, the lower the pumping rate.

d. Air entering the airlift pump tube at a point submerged in the electrolyte reduces the pressure at the base of the tube. Denser electrolyte enters the tube at the bottom, is drawn up to the top, and is discharged over the top of the electrolyte (Figure 223−10). The pumping rate varies with battery types and electrolyte levels. Typical pumping rates range from 300 to 600 cm^3/min (0.01 to 0.02 ft^3/min) of electrolyte, depending upon the cell geometry and flow rate.

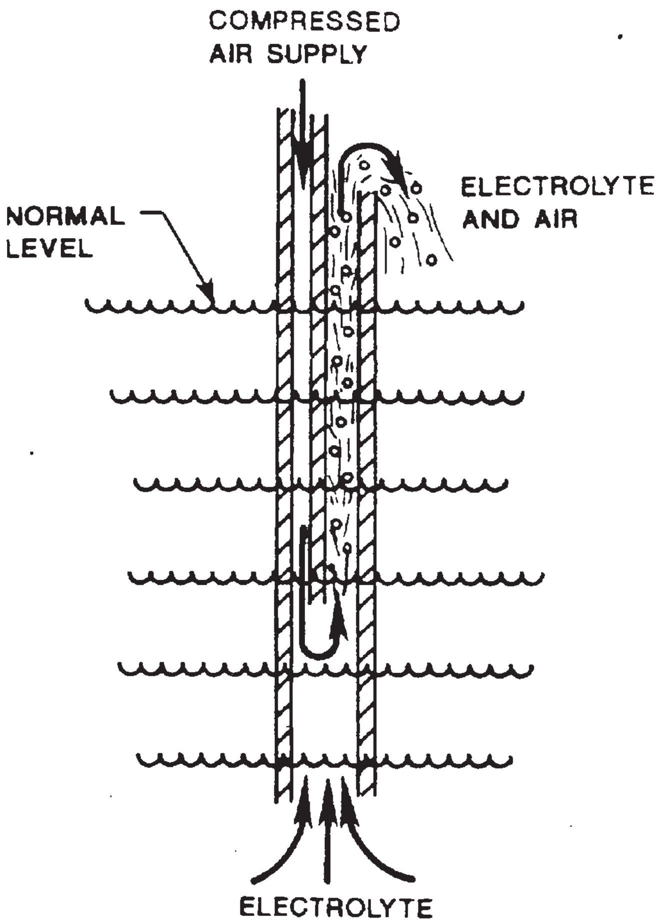


Figure 223−10. Airlift Pump

223−1.9.16 GROUND RESISTANCE METERS. Ground resistance meters are of two basic types:

a. Most submarines have a ground detector ohmmeter which reads the resistance to ground directly in ohms. This device is essentially an ohmmeter that measures the resistance between the electrical system and the ground. These instruments should be used in accordance with the directions given in the instruction book, which also discusses the theory of operation.

b. The small number of submarines without the direct reading ground detector ohmmeter have permanently-installed ground detector voltmeters. The resistance to ground can be calculated from the ground detector voltmeter readings in accordance with the instructions given in the propulsion instruction book.

223−1.9.17 BATTERY TEST KIT. Battery test equipment listed in Table 223−3 is available as parts listed under Allowance Equipment List, AEL 1−911393001.

223−1.9.18 INSULATED TORQUE WRENCH. Each submarine is equipped with two insulated breakaway-type torque wrenches (manufactured by Consolidated Devices Incorporated under part number CDI 50T−2RXS (NSN 5120−01−036−8942)) to be used only during installation and torque checks of battery intercell connector hardware. The wrench has been calibrated to break away at 525 inch-pounds (60 newton-meters) of torque and cannot be recalibrated without destroying the special insulating feature of the wrench. Wrenches found out of calibration, in the clockwise direction only, should be returned to Mare Island Naval Shipyard, Code 134.13, for calibration and restoration of insulation. For each wrench received a replacement wrench will automatically be issued to the sending activity. No special requisition is necessary. Standard six-point, 3/4 in. (19 mm) (NSN 1H−5120−00−788−5407) and 13/16 in. (21 mm) (NSN 1H−0000−LL−CJA−4475) impact sockets should be requisitioned with each wrench to prevent stripping hardware and to prevent contact between the wrench head and adjacent bus bars. Only the 3/4 in. (19 mm) impact socket is required when stainless steel hardware is installed.

223−1.9.19 QUICK-OPENING DISCONNECTS. Quick-opening disconnects are installed in the battery well near the electrical ends of the battery. They are operated locally from inside the well to isolate the battery during battery or dc switchboard maintenance.

223−1.10 BATTERY LIFESPAN GUARANTEE

223−1.10.1 GUARANTEE TERMS. Submarine main storage batteries are guaranteed by the manufacturer for a term of service life stipulated in the delivery contract. This guarantee is based on the expected calendar life and on the expected number of complete charge and discharge cycles (defined in paragraph 223−3.1.10) that the battery should be able to complete. For specific terms, see paragraphs 223−5.1.2.3 and 223−5.1.2.4. This age guarantee begins with the date the battery is filled and charged, or two years from date of manufacture, whichever occurs first. It is enforceable against the contractor if the capacity of the battery falls below 80 percent of rated capacity prior to the expiration of the guarantee period, provided that failure is not due to violation of approved instructions. The use life or expected number of cycles is measured in equivalent (standard) cycles explained in paragraph 223−1.10.2.

NOTE

> Operating personnel should be familiar with the guarantee (Table 223−2) for their particular battery so that no violation of existing instructions or good engineering practice invalidates the guarantee.

223−1.10.2 EQUIVALENT CYCLES. For the purpose of computing battery life, an equivalent cycle is defined as 5000 Ah of charge for the Guppy I Mod C battery, 6500 Ah of charge for the Guppy I Mod E battery, and 10,000 Ah of charge for the TRIDENT battery. The number of equivalent cycles a battery has completed is computed by dividing the total number of Ah the battery has been charged, after installation, by the number of Ah per equivalent cycle. For example, a GUPPY I Mod C battery receives a total of 500,000 Ah of charge after it is installed onboard. The number of equivalent cycles, to the nearest tenth, is 500,000/5000, or 100 (see paragraph 223−3.1.11).

223−1.10.3 ACTION IN CASE OF FAILURE. Whenever it becomes apparent that the battery will not meet the guaranteed life, a detailed report covering the deficiencies shall immediately be forwarded to NAVSEA.

223−1.10.4 FINAL CAPACITY TEST. A final capacity test shall be run to determine the capacity at the time of removal when the battery has not met the guaranteed life. This capacity test shall be made as near as possible to the time of removal, but not more than two weeks before the battery is unbussed.

SECTION 2.
SHIPPING, STORING, PREPARING AND INSTALLING BATTERIES

223−2.1 SHIPMENT AND STORAGE

223−2.2 SPECIAL INSTRUCTIONS

Where special instructions are issued covering shipment and storage, they shall be followed rather than the instructions in this volume.

223−2.3 SHIPMENT

Complete cells are shipped dry and uncharged, or wet and fully charged, as specified in the contract. All cells shall be shipped according to the Department of Transportation (DOT) or equivalent military specification.

a. When shipped dry, the cells are without electrolyte, but are otherwise complete. Replacement batteries and spare cells are usually shipped dry and completely assembled.

b. Cells to be shipped wet are filled with electrolyte and fully charged to the maximum specific gravity as close to the shipping date as practical. Batteries for new construction ships are usually shipped wet from the manufacturer. A record of individual cell readings and date of charge will be furnished to the private building yard or naval shipyard by the battery manufacturer. Cells are to be inspected to verify that they have no leaks and are safe to handle, prior to shipment.

c. Items such as special tools, bolts, nuts and washers are shipped with the first truckload of new cells whenever practical, to facilitate handling and care of cells upon arrival at their destination.

d. A turn−in document (TID) shall accompany all battery deliveries. These documents must contain a valid National Stock Number (NSN). In addition, the TID will state the hazardous material contained in the crates by chemical name or chemical analysis.

223−2.3.1 CRATING OF CELLS. All cells are shipped in secure wooden packing cases labeled on the top side with “THIS SIDE UP.” The packing cases are plainly marked to indicate the contract number, type, consignee, and case and cell numbers. Cases containing instructions for filling and initial charging, service manuals, and record books are so marked. Tops of cases that contain spare cells are painted gray and marked SPARE.

223−2.3.2 INSPECTION UPON ARRIVAL. When a battery arrives at a naval shipyard, an inspector familiar with storage batteries shall be detailed for inspection. When a battery arrives at a private shipyard, the Supervisor of Shipbuilding shall detail an inspector familiar with storage batteries. In each case, the battery manufacturer should be notified of the inspection date and invited to have a representative present. Whenever possible, this inspection should be conducted prior to or during the removal of the battery from the carrier in order that breakage resulting from rough handling during shipment may be definitely established. Should damage be discovered after unloading, the carrier and the cognizant Defense Contract Administration Services (DCAS) inspector at the battery company should be notified at once. In the case of batteries that have been shipped unusually long distances, or where rough handling in shipment is considered probable, the rows of cells at each end of the trailer must be given an especially careful inspection, since these are the ones most likely to be damaged.

Prepare equipment and rigging as follows:

a. Prior to cell handling or inspection, cell−lifting gear and other necessary equipment must be at hand and properly rigged.

b. Inspect cells shipped dry as follows:

1. Remove packing case covers.

2. Examine the cell tops for breakage of jar or jar cover. Take special care in inspecting jar corners.

3. Where damage is suspected, lift cells from packing cases and inspect for breakage of jar or jar cover and for condition of terminal posts.

4. Replace cell in packing case and secure packing case cover.

c. Inspect cells shipped wet as follows:

1. Inspect packing case covers.

2. Examine tops of cells for possible breakage of parts, with special attention given to the jar corners.

3. Flash arrester (vent cap) should be in place.

4. Examine packing cases for signs of jar leakage or loss of electrolyte by spillage in transit. Where breakage is suspected, cells should be removed from packing cases for further examination.

5. Remove service caps and note the height of electrolyte, paying special attention to any cell in which the level of electrolyte is markedly lower than in surrounding cells. If a broken or leaking jar is found, substitute a spare cell. The manufacturer should be notified of damaged cells and disposition instructions request. The damaged jar should be drained to preclude leaking of the electrolyte. If the jar is undamaged and electrolyte has spilled, refill to normal level with electrolyte of the same specific gravity as that in other cells.

6. When the average level of electrolyte in all cells has fallen to the minimum permissible level, add water from a demineralized (DI) water supply (paragraph 223−5.3.3.1). Watering to the minimum level specified by the applicable service manual will not require any special charging.

7. Take specific gravity readings and record in battery entry log. If reading is 30 points (0.030) below fully charged condition, the battery must be given a freshening (paragraph 223−2.7) charge at once.

8. Cells should be left in their packing cases with packing case covers in place until ready to lower into the ship.

223−2.3.2.1 Care During Inspection and Handling. Great care must be exercised during inspection and subsequent handling of cells to prevent breakage of jars or covers, or damage to other parts. The weakest parts of the jars are the bottom edges. Under no circumstances shall jars be dragged on the bottom edges instead of on the feet that are provided to take the weight of the cell. Failure to observe this precaution will almost surely result in a fracture around the feet or breakage of jar corners. Installation and wedging must be done with extreme care, especially when cell electrolyte temperature is below 15.6° C (60° F).

223−2.4 TIMING BATTERY ARRIVAL

The building yards shall set the date of delivery of the wet battery (paragraph 223−2.3) so as to minimize the time between arrival of the battery and installation in the submarine. When building schedules will not permit the battery to be installed prior to the date of the first freshening charge (paragraph 223−2.6), the wet cells shall be stored in a suitable place (paragraph 223−2.5) equipped with charging connections.

223−2.5 DRY CELL STORAGE

Cells that are not to be installed immediately shall be stored in their packing cases in a clean, dry, well−ventilated place and maintained at a moderate temperature. Heating must be provided, if necessary, to keep the temperature above 1.7° C (35° F). Complete cells shipped in the dry condition may be kept in storage for extended periods of time. A certain amount of deterioration will occur, however, which can be minimized by maintaining low humidity within the storage spaces. Spare cells should be kept in their packing cases until ready to be installed in the battery well.

223−2.6 WET BATTERY STORAGE

The instructions of paragraph 223−2.5 also apply to a battery filled and charged at a naval shipyard and to a battery received wet and charged.

NOTE

> The specific gravity of a wet battery in storage shall not be adjusted without authority from the Naval Sea Systems Command (NAVSEA).

223−2.7 FRESHENING CHARGES DURING STORAGE

A freshening charge is a charge given to restore the fully charged condition of an idle battery that has lost part of its capacity by self−discharge. Unless otherwise specified in the approved manufacturer's instructions, the freshening charge rate is the same as the finishing rate shown on the curves and data plan for the type of battery. Freshening charges shall be conducted in accordance with the manufacturer's technical manual as approved by NAVSEA. The technical manual should be on hand prior to battery arrival. If no technical manual has been received within 30 days of the battery arrival date, the Supervisor of Shipbuilding (in the case of a private shipyard) or the Shipyard Commander (in the case of a naval shipyard) shall request charging instructions from NAVSEA.

223−2.8 CELL PREPARATION

223−2.8.1 INSTRUCTIONS. The manufacturers of cells shipped dry furnish complete instructions for putting them in service. The battery technical manual or separate instructions are packed with the first cell shipment. Before any cell is removed from its packing case, the instructions contained in this manual relating to placing in service, and such additional instructions as may be supplied by the battery manufacturer or NAVSEA, shall be carefully studied and understood. Such instructions are an intrinsic part of the contract under which the battery is furnished and departure from the instructions may invalidate the manufacturer's guarantee. In case of a discrepancy between the manufacturer's instructions and this volume, NAVSEA shall be notified and a decision requested. Cells shipped wet are ready for installation when received; cells shipped dry should be prepared for installation in accordance with the instructions furnished by the manufacturer. Spare dry cells and batteries should be handled in accordance with paragraphs 223−2.8.1.3 and 223−2.8.1.4.

223−2.8.1.1 Contractor Notification. Contracts for new batteries provide that the battery manufacturer be allowed to have a representative present to witness the placing in service and the installation of the battery. Consequently; the Commanding Officer, in the case of a submarine in commission; or the Supervisor of Shipbuilding, in the case of new construction; or Commander of the Naval Shipyard, will notify the cognizant Defense Contract Administration Service (DCAS) representative, as early as practical, of the proposed date for placing in service and for installation of the battery, in order to allow a representative of the contractor to be present.

223−2.8.1.2 Materials to be on Hand. In order to prevent delay during preparation of dry cells and during installation, it is important that all required battery parts be on hand. Ascertain what items may be required (that is, sulfuric acid, DI water, wedges, cell connectors, bolts and nuts, paraffin, baking soda, rubber tape, sealing compound, individual cell voltmeter wire, rubber gloves, boots, aprons and face shields), and arrange for their supply (paragraph 223−7.2.4.3). A complete set of plans for the battery and battery tanks, details of wedging and cribbing, and cell and cable connections should also be on hand.

a. Examine the tackle and lifting gear to be used in handling cells and see that they are in proper operating condition and of sufficient strength for the weight of a cell and such additional strains as may be encountered. Ensure all tools necessary are on hand and in good condition.

b. Equipment to be used for giving the initial charge and test discharges of cells furnished dry should be inspected and verified that it is of sufficient capacity and is in proper condition.

c. Sufficient intercell connecting cable should be available for connection to all cell terminal posts.

d. Lifting device, as furnished by the building or maintenance activity.

e. Chain fall of sufficient size and capacity to take weight of cell.

f. Seal−nut wrench furnished with battery (Figure 223−11).

NOTE

Cells shall be left in their packing crates between filling and installation.

223−2.8.1.3 Spare Cells. Each battery installing activity is authorized to maintain a maximum of six wet spare cells for each battery type routinely installed by that activity. When a new battery is drawn from supply for activation, wet spares on hand are connected for initial cycling of the new battery. The total number of cells subjected to initial cycling shall be 132 or 134 depending on the battery type. After cycling, the six weakest cells are designated the spare cells and are made available to support the installation in case of individual cell problems. After battery installation, spare cells are returned to the installing activity to be maintained for use during the next battery activation. During the next activation a different group of six cells will be the weakest and those cells designated as spare cells. When managed in this manner, spare cells are maintained relatively new. If a spare cell is used during an installation and not replaced by repair of the cell it replaced, or if a cell repeats as a weak cell, a dry replacement spare cell is drawn from supply with the next complete battery. The installing activity shall notify the manufacturer of a cell repeating as a weak cell and shall maintain the cell as a healthy spare until inspection/evaluation of the cell is conducted.

223−2.8.1.4 Spare Batteries. Charleston Naval Shipyard (CNSY) maintains a spare wet charged TLX−39B battery

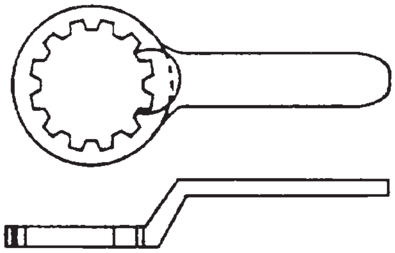


Figure 223−11. Seal-nut Wrench

for use in emergencies such as urgent overseas renewals or trucking accident casualties. CNSY will assemble spare wet charged ASB−49 and TRIDENT batteries, for East Coast installations, as wet spare cells accumulate with each battery installation. A spare battery is maintained relatively new by installing it at the next scheduled installation of that battery type. When a battery renewal is scheduled for CNSY, a dry battery is drawn from supply and activated. This new battery is designated the wet spare and the existing wet spare battery is installed, thus maintaining a relatively new spare at all times. Once spare batteries are assembled, CNSY manages spare cells in accordance with paragraph 223−2.8.1.3, Section 5.

223−2.8.2 TERMINAL RESISTANCE CHECK. Terminals may become very hot due to high electrical resistance resulting from a poor metallurgical bond between the tin−plated copper terminal insert and the surrounding lead casting. It is, therefore, important to check terminal contact resistance prior to assembly or cell activation. Elements are inspected during manufacture and each lead bus is stamped 0 if acceptable. The bond may weaken during shipment and storage and shall be checked prior to installation using a J. W. Dice Co. model 150 or 153 or equivalent microhmmeter. Both positive and negative terminals of all elements of cells, with or without water−cooling provision, shall have each terminal resistance, R_B, of Figure 223−12, measured separately from the top of the copper terminal to the top of the surrounding lead casting at the points shown. To be accepted, each terminal resistance R_B reading shall be less than 13 micro−ohms. Cells not meeting this criterion shall be rejected and the readings reported to NAVSEA. NAVSEA shall determine disposition of the failed units.

223−2.9 ELECTROLYTE

223−2.9.1 CARE IN HANDLING AND STORING ACID. The following paragraphs relate to general care and precautions in handling and storing sulfuric acid (H_2SO_4).

223−2.9.1.1 Protective Handling Equipment. Personnel engaged in handling acid or electrolyte shall wear rubber aprons, rubber boots, rubber gloves, rubber or plastic chemical goggles and suitable head gear, so that the acid cannot come in contact with clothing or skin. In particular, the face must be guarded by a full face shield. For treatment of acid or electrolyte burns see paragraph 223−9.2.4.1.

223−2.9.1.2 Storage. Containers of sulfuric acid should be stored in a place where freezing cannot occur. The freezing temperature of sulfuric acid solutions is shown in Table 223−4. It will be noted from Table 223−4 that a reduction of specific gravity of concentrated acid from 1.835 to 1.801 changes the freezing temperature from −33.9° C to 5.1° C (−29° F to 41° F). Since acid is highly hygroscopic, extreme care must be taken to ensure that the containers are absolutely airtight to prevent absorption of water from the air. Entry of even a small quantity of water into an open container may reduce the specific gravity sufficiently to cause the jar to break in cold weather, with consequent grave danger of acid burns to personnel. At any temperature, even the addition of a small quantity of water to a container of strong acid will instantly cause heat, possibly enough to cause an explosion. Therefore, containers of acid shall be kept securely stoppered.

223−2.9.2 ELECTROLYTE FOR FILLING. In order to arrive at the proper specific gravity when the battery is fully charged and in all respects ready for service, electrolyte of a different specific gravity from that ultimately desired must be used for filling the cells. Information on the proper specific gravity and quantity for filling is furnished in the instructions supplied by the manufacturer with new cells. The quantity required for filing is given in gallons and pounds, under Cell Data in the curves and data plan for each type of storage battery.

223−2.9.2.1 Determining Amount of Water and Acid for Mixing Electrolyte. The following information is presented in Table 223−5:

a. The number of parts of water, by mass, to which a unit mass of acid (specific gravity 1.350, 1.400 or 1.835) must be added to make electrolyte of a desired specific gravity.

b. The number of parts of water, by volume, to which a unit volume of acid (specific gravity 1.350, 1.400 or 1.835) must be added to make electrolyte of a desired specific gravity.

c. The mass units, in kilograms or pounds, of acid (specific gravity 1.350, 1.400 or 1.835) needed to make a volume of 100 volume units, in liters or gallons, of electrolyte of a desired specific gravity.

d. As indicated in note 1 of Table 223−5, the specific gravity of the concentrated acid is based on a temperature of 16° C (60° F), compared to water at 16° C (60° F). The specific gravity of the dilute acid under the desired electrolyte specific gravity is based on a temperature of 26.7° C (80° F) compared to water at 16° (60° F). The specific gravity

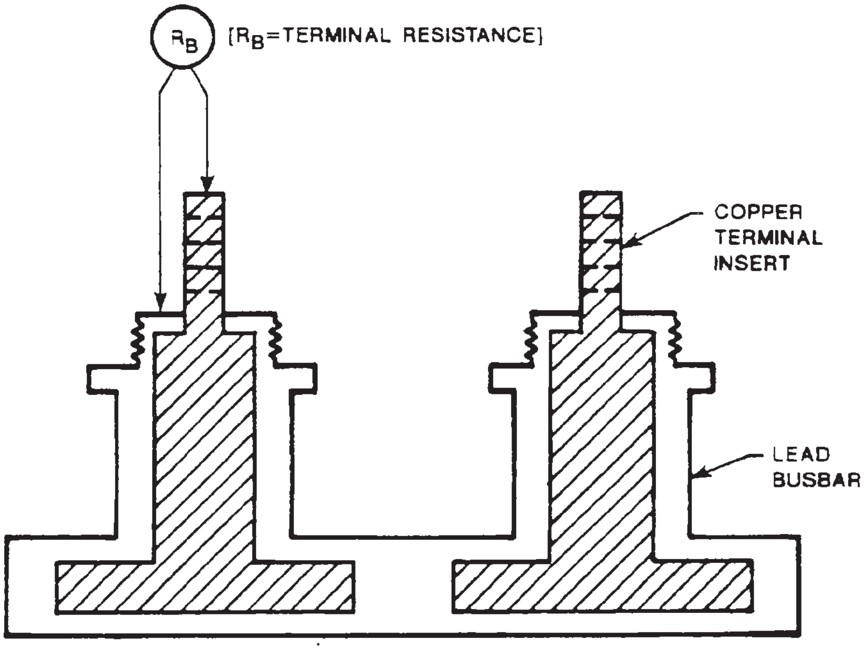


Figure 223−12. Terminal Bus Bar

of the concentrated acid conforms to commercial usage. The specific gravity of the dilute acid conforms to Navy usage.

223−2.9.2.2 Use of Table 223−5. Use data in Table 223−5 as indicated in the following example:

a. For an example of the use of Table 223−5, the curves and data plan for a GNB−type TLX−39B GUPPY I Mod C battery indicate that the filling electrolyte should have a specific gravity of 1.260 for a full charge specific gravity of 1.285 and that 18.5 gallons of electrolyte are needed per cell. Assuming that 126 cells are to be filled, 18.5 x 126 = 2331 gallons of electrolyte are needed. Reference to Table 223−5 shows, by interpolation, that 26.2 gallons of 1.835 acid are needed to make 100 gallons of 1.260 electrolyte. Hence, a total of 611 gallons of 1.835 acid will be needed to make 2331 gallons of electrolyte.

b. The same example using liters (rather than gallons) would require 70 liters of electrolyte per cell. Assuming that 126 cells are to be filled, 70 x 126 = 8820 liters of electrolyte are needed. Reference to Table 223−5 shows that 26.2 liters of 1.835 acid are needed to make 100 liters of 1.260 electrolyte. Hence, a total of 2313 liters of 1.835 acid will be needed to make 8820 liters of electrolyte.

223−2.9.2.3 Specifications for Acid and Water. The following specification shall be observed in preparing electrolyte:

Table 223–4. FREEZING TEMPERATURES OF SULFURIC ACID SOLUTIONS

Specific gravity	Temperature	
	°C	°F
1.150	-15.0	+5
1.210	-30.5	-23
1.250	-51.7	-61
1.280	-68.3	-91
1.300	-70.5	-95
1.350	-48.9	-56
1.400	-36.1	-33
1.500	-28.9	-20
1.700	-14.4	+06
1.726	-2.61	+27
1.768	+7.8	+46
1.790	+8.0	+46.5
1.796	+6.4	+43.5
1.801	+5.1	+41
1.807	+3.3	+38
1.812	+0.6	+33
1.818	-4.1	+24.5
1.824	-10.3	+13.5
1.830	-18.3	-1
1.835	-33.9	-29

a. Sulfuric acid conforming to Fed Spec O–S–801, **Sulfuric Acid, Electrolyte; for Storage Batteries** , must be used. (See restricting caution in note 4, Table 223–5, which gives electrolyte preparation data.) The acid shall be tested before use and shall be used only if it is practically colorless in accordance with test specified in O–S–801 and analysis shows that it does not contain more than the maximum allowable impurities in parts per million (ppm) (Table 223–6).

b. Only DI water for filling conforming to Fed Spec O–B–41, **Battery Water**, shall be used. Water shall be tested prior to use to determine that it does not contain more than the maximum allowable impurities in ppm (Table 223–7).

223–2.9.2.4 Mixing Tank for Electrolyte. Electrolyte should be prepared in an approved mixing tank, large enough to hold the solution for the total number of cells to be filled at one time. If an approved tank is not available, in an

Table 223−5. DATA FOR PREPARING ELECTROLYTE FROM ACID

Desired electrolyte specific gravity	Mass of water per unit mass of acid			Volume of water power unit volume of acid			Mass units of acid to make 100 mass units of electrolyte			Volume units of acid to make 100 volume units of electrolyte		
	1.350	1.400	1.835	1.350	1.400	1.835	1.350	1.400	1.835	1.350	1.400	1.835
1.10	1.98	2.33	5.21	2.67	3.26	9.55	033.6	30.0	16.1	027.5	23.7	09.7
1.11	1.71	2.03	4.66	2.31	2.84	8.45	036.9	33.0	17.7	030.5	26.3	10.8
1.12	1.51	1.81	4.24	2.04	2.53	7.79	039.8	35.6	19.1	033.2	28.6	11.7
1.13	1.34	1.62	3.89	1.81	2.27	7.15	042.7	38.2	20.4	035.9	30.9	12.6
1.14	1.19	1.45	3.58	1.61	2.03	6.57	045.7	40.8	21.8	038.7	33.4	13.6
1.15	1.05	1.30	3.28	1.42	1.82	6.02	048.8	43.5	23.3	041.7	35.9	14.7
1.16	0.95	1.18	3.07	1.28	1.65	5.63	051.3	45.8	24.6	044.3	38.2	15.6
1.17	0.85	1.07	2.86	1.15	1.50	5.25	054.0	48.3	25.9	047.1	40.5	16.6
1.18	0.75	0.96	2.65	1.01	1.35	4.87	057.2	51.0	27.4	050.1	43.2	17.7
1.19	0.67	0.87	2.49	0.90	1.22	4.57	059.8	53.5	28.6	053.1	45.8	18.7
1.20	0.59	0.78	2.31	0.80	1.09	4.24	062.8	56.2	30.2	056.2	48.5	19.9
1.21	0.52	0.70	2.18	0.70	0.98	4.00	065.7	58.8	31.4	059.4	51.2	20.8
1.22	0.46	0.64	2.05	0.62	0.90	3.76	068.5	61.0	32.8	062.3	53.5	21.9
1.23	0.41	0.58	1.94	0.55	0.81	3.56	070.9	63.3	34.0	065.0	56.0	22.9
1.24	0.36	0.52	1.83	0.49	0.73	3.36	073.5	65.8	35.3	068.0	58.6	24.0
1.25	0.31	0.46	1.73	0.42	0.64	3.17	076.3	68.5	36.6	071.1	61.5	25.1
1.26	0.26	0.42	1.64	0.35	0.59	3.01	079.4	70.5	37.9	074.5	63.7	26.2
1.27	0.22	0.37	1.55	0.30	0.52	2.84	082.0	73.0	39.2	077.5	66.6	27.3
1.28	0.18	0.32	1.47	0.24	0.45	2.70	284.7	75.7	40.5	080.8	69.6	28.4
1.29	0.15	0.29	1.40	0.20	0.41	2.57	087.0	77.5	41.7	083.5	71.8	29.5
1.30	0.12	0.25	1.33	0.16	0.35	2.44	089.2	80.0	42.9	086.5	74.6	30.6
1.31	0.09	0.22	1.27	0.12	0.31	2.33	091.7	82.0	44.0	089.5	77.2	31.6
1.32	0.06	0.18	1.20	0.08	0.25	2.20	094.3	84.7	45.5	092.7	80.3	32.9
1.33	0.03	0.15	1.15	0.04	0.21	2.11	097.0	87.0	46.5	096.1	83.0	33.9
1.34	0.00	0.12	1.09	0.00	0.17	2.00	100.0	89.3	47.8	100.0	86.0	35.1
1.35	---	0.09	1.04	---	0.13	1.96	---	91.7	49.0	----	89.0	36.2

NOTES:

1. Specific gravity of acid is at $\frac{15.6°C}{15.6°C}\left(\frac{60°F}{60°F}\right)$ which conforms to Fed. Spec. O-S-801. Specific gravity of electrolyte is at $\frac{26.7°C}{15.6°C}\left(\frac{80°F}{60°F}\right)$.
2. Mass units can be kilograms or pounds.
3. Volume units can be liters or gallons.

CAUTION: The use of acid for the purpose of preparing electrolyte or for the adjustment of specific gravity is authorized only for shore activities or for ships designated as Intermediate Maintenance Activities (IMA).

Table 223−6. MAXIMUM ALLOWABLE IMPURITY LEVELS IN 1.835 SPECIFIC GRAVITY ACID FOR MIXING

Impurities	Chemical Identification	Parts per Million (ppm)
Ammonium	NH_4	10
Antimony	Sb	1
Arsenic	As	1
Chloride	Cl	10
Copper	Cu	50
Iron	Fe	50
Manganese	Mn	0.2
Nickel	Ni	1
Nitrates	NO_3	5
Platinum	Pt	0.1
Selenium	Se	20
Sulfurous acid	SO_2	40
Zinc	Zn	40
Fixed residue	---	300

emergency a wood tank that has not been used for any other purpose may be substituted, but prior to use the inside shall be given at least two coats of an approved acidproof asphaltum paint to prevent the electrolyte from coming in contact with the bare wood. It is particularly important that the interior of the tank have no exposed nail heads or other metallic surfaces. Pipes and fittings used for distributing acid should be of hard rubber or lead. Plastics may be used only if specifically approved by NAVSEA. Tanks, pipes and fittings constructed of metal other than lead are not suitable for use in mixing and distributing battery electrolyte, even though they may be protected from the acid by an insulating lining such as rubber; cracks or porosity in the lining will introduce harmful contaminants into the electrolyte. Glass−lined tanks in accordance with Pfoudler Company dwg R272−0824−27, sheets 1 through 5, or equal may be used in lieu of lead−lined tanks.

223−2.9.2.5 Specification for Filling Electrolyte. Electrolyte must not be used for filling cells unless it is practically colorless in accordance with the test specified in O−S−801, and unless analysis of the sample submitted to the laboratory shows that it contains not more than the maximum allowable impurities in parts per million (ppm) in 1.255−specific−gravity sulfuric acid (Table 223−8). These limits are based on a specific gravity of 1.255. If the filling electrolyte is not 1.255, the allowable impurities shall be determined as follows:

Table 223−7. MAXIMUM ALLOWABLE IMPURITY LEVELS IN WATER

Impurities	Parts per million (ppm)
Ammonium (NH_4)	8
Calcium and Magnesium Oxide	40
Chloride	5
Copper	2.5
Iron [1]	0.5
Nickel	0.2
Nitrates (NO_3)	10
Nitrites (NO_2)	5
Organic and volatile matter	50
Suspended matter	Trace
Total solids	100
1. Iron oxide suspended in battery water shall be included in the total iron.	

a. Determine the percent of 1.835 acid by mass in the dilute acid. For example, reference to Table 223−5 shows that 1.255 electrolyte contains 37.3 pounds of 1.835 acid per 100 pounds of electrolyte or 37.3 kilograms of 1.835 acid per 100 kilograms of electrolyte. Hence, 1.255 acid consists of 37.3 percent of 1.835 specific gravity acid and 62.7 percent of water.

b. Multiply the allowable ppm of impurity in acid of Table 223−6 by the percent acid and divide by 100 to obtain the maximum ppm of impurities introduced by the acid. Proceed similarly for the water. Add the results to obtain the maximum ppm of allowable impurities in the dilute electrolyte.

223−2.9.2.6 Analysis of Electrolyte. After preparation of electrolyte for filling dry cells, at least a 150 ml (or 5 ounce) sample of the electrolyte shall be submitted to a Government laboratory for a record spectro−analysis prior to use, in order to ensure that impurities have not been added in the mixing process. During cell filling a sample should be taken from the filling hose prior to filling the first and last cells, these samples shall be analyzed for conformance to requirements of Table 223−8. The results of this analysis, together with the specific gravity of the sample, shall be entered in the battery record book.

Table 223−8. MAXIMUM ALLOWABLE IMPURITY LEVELS IN 1.255 SPECIFIC GRAVITY ELECTROLYTE

Impurities	Chemical identification	Parts per million (ppm)
Ammonium	NH_4	8
Antimony	Sb	0.3
Arsenic	As	0.3
Calcium and Magnesium Oxide	---	25
Chloride	Cl	6
Copper	Cu	20
Iron	Fe	18
Manganese	Mn	0.07
Nickel	Ni	0.4
Nitrates	NO_3	8
Nitrites	NO_2	3
Platinum	Pt	0.03
Selenium	Se	7
Sulfurous acid	SO_2	14
Zinc	Zn	14
Fixed residue	---	111
Organic and volatile material	---	31

223−2.9.2.7 Instructions for Mixing Electrolyte.

WARNING

Sulfuric acid can be dangerous. To avoid violent reaction and painful burns, sulfuric acid must always be poured into the water and not the water poured into the acid.

See paragraph 223−2.9.1.1 for protective equipment to be used while handling acid. The acid must be added to the water slowly and cautiously to prevent excessive heating and splashing as the strong acid will cause painful burns. The solution should be stirred continuously while the acid is being poured into the water, to prevent the heavier acid from flowing to the bottom of the tank without mixing. When concentrated acid is added to water, the solution becomes very hot and must be allowed to cool to approximately room temperature before final specific gravity readings are taken prior to pouring into the cells. The best way to stir electrolyte is by using clean, compressed air carried to the bottom of the tank through a rubber hose having no metallic fitting exposed to the acid. If compressed air is not available, use a wooden paddle painted with at least two coats of an approved acid−proof asphaltum paint. With either stirring method, extreme care should be used to avoid splashing. For the precautions to be observed in storing and handling acid and for treatment of acid burns, see paragraph 223−9.2.4.1.

223−2.9.3 DISPOSAL OF ELECTROLYTE. Electrolyte shall be neutralized and disposed of in accordance with NSTM Chapter 593, **Pollution Control**, regardless of quantity.

223−2.10 CELL FILLING AND INITIAL CYCLING

223−2.10.1 INSTRUCTIONS FOR FILLING CELLS. Fill each cell to the level specified by the manufacturer's approved technical manual by continuous pouring. Never partly fill a cell because the resulting unequal heating may cause the plates to warp. After the cell stands for a time, the electrolyte level will drop and should be restored as described in the manufacturer's technical manual.

223−2.10.2 SOAK TIME. Cells shall have a minimum soak time of 36 hours and a maximum soak time of 48 hours for any cell in the battery. This soak period provides for electrolyte saturation of the plates and separators and also provides a cooling period before initial charge is applied. Saturation cooling time will be not less than 36 hours and not until electrolyte temperature falls to less than 38° C (100° F). Do not, however, allow more than 48 hours to elapse after filling any cell before starting the initial charge, even though the temperature may still be higher than recommended, that is 38° C (100° F). The extended soak time will yield higher initial capacities and, after installation, batteries will reach maximum capacity after completing fewer cycles. After completion of the soak period, the cell specific gravity readings should be taken and should conform to the specific gravity requirements of section 223−1.6. Should the specific gravity need correction, follow the procedures of section 223−2.10.3.2 prior to initial charge.

223−2.10.3 INITIAL CHARGE. The initial charge is the most important one given a battery. If that charge is not performed strictly according to instructions, or if terminated prematurely, the battery may be damaged and never develop full capacity. The initial charge shall always be con−

ducted in accordance with the manufacturer's technical manual. The details of the technical manual for the initial charge depend upon the manufacturer, the type of element and nature of the processing to which the element has been subjected. The manufacturer's technical manual is packed with cell No. 1 and at least in every fiftieth cell packing case. The cases which contain instructions are so marked. Every effort is made to ensure that the proper instructions are furnished with each set of cells.

NOTE

> Samples of the electrolyte dispensed from the filling hose prior to filling the first and following filling of the last cell shall be analyzed prior to the initial charge. The requirements of Table 223−8 apply. Notify NAVSEA of any failures. Following initial charge, cell specific gravity readings should be made and corrections performed as necessary.

223−2.10.3.1 Interruption of Initial Charge. If required by circumstances, initial charging of batteries may be interrupted as long as a minimum of 75 percent of the required ampere−hours of charge has been given and the battery has been gassing for at least five hours. If the charge has been interrupted, however, battery rest periods shall be eliminated, even if specified in the manufacturer's technical manual. A full set of individual cell voltage readings (on charge) and specific gravity readings shall be made prior to the interruption and no such interruption shall exceed 72 hours.

223−2.10.3.2 Adjustment of Electrolyte Specific Gravity. If the manufacturer furnishes instructions for adjusting the specific gravity of the electrolyte these instructions shall always be followed. If such instructions are not furnished by the manufacturer, the specific gravity of the electrolyte in each cell shall be adjusted, upon completion of the initial charge, to be within the limits of nominal specific gravity + 0.005 (paragraph 223−5.3.4.10) as follows:

1. Allow cells to stand on open circuit until electrolyte temperature has dropped below 38° C (100° F) and electrolyte level has remained constant for at least eight hours.

2. Take and record specific gravity, temperature and height of electrolyte in each cell; correct specific gravity of each cell for temperature and height of electrolyte (if applicable) as noted in paragraph 223−3.1.6.2. Tabulate corrected specific gravity for each cell.

3. From each cell with a corrected specific gravity below the lower limit, remove the volume of electrolyte specified in paragraph 223−2.10.3.2(6) and replace with an equal volume of 1.350 specific gravity electrolyte. However, for USS DOLPHIN (lead−antimony cells) with a corrected specific gravity less than 20 points below lower limit, see paragraph 223−2.10.3.2(8).

CAUTION

> Acid stronger than 1.350 specific gravity must never be added to a battery because it will damage the plates.

4. From each cell with a corrected specific gravity above the upper limit given in paragraph 223−5.3.4.11, remove volume of electrolyte specified in (6) below and replace with an equal volume of water.

5. Electrolyte should be removed either by pumping it through electrolyte changing tubes or by pumping out electrolyte above the top of the plates through the service opening.

6. The volume of electrolyte to be removed for making small specific gravity changes (not over 20 points, that is, from 1.260 to 1.280) shall be determined from the following equation:

$$X = V \frac{G_3 - G_1}{G_2 - G_0}$$

Where:

X = Volume of electrolyte to be removed from cell and replaced by an equal volume of mixing electrolyte

V = Total volume of electrolyte in cell when filled to proper level. This may be obtained from volume of pouring acid shown on the curves and data plan

G_o = Specific gravity of electrolyte in cell corrected for temperature, but not corrected for height of electrolyte

G_1 = Specific gravity of electrolyte in cell corrected for temperature and height of electrolyte

G_2 = Specific gravity of mixing electrolyte. Specific gravity of 1.350, if 1.350 specific−gravity acid is added to raise electrolyte specific gravity; or 1.000, if water is added to decrease it

G_3 = Specific gravity desired in cell with electrolyte adjusted to proper level and electrolyte temperature equal to 26.7° C (80° F).

7. The specific gravity, G_3, will be obtained when:

a. The calculated volume, X, has been removed from cell.

b. X has been replaced by an equal volume of mixing electrolyte.

c. Water has been added, if necessary, to bring electrolyte to normal level.

d. The electrolyte has been thoroughly mixed and brought to 26.7° C (80° F).

8. Note: USS DOLPHIN (lead−antimony cell). To raise the corrected specific gravity a small amount (not over 20 points) for a lead−antimony battery, allow level to drop by evaporation and electrolysis until the full charge specific gravity, corrected for temperature to 26.7° C (80° F), but not for height, is within the desired range. Then fill to normal level with electrolyte of nominal specific gravity.

223−2.10.3.3 Checking Specific Gravity Adjustment. The accuracy of the specific gravity adjustment should always be checked. This check may be made either after the addition of mixing electrolyte or after the addition of mixing electrolyte followed by the addition of water, if necessary, to bring the electrolyte to the normal level. To make this check, give the battery a mixing charge at the finishing rate, until the specific gravity has remained unchanged for at least one hour. Following the charge, allow the battery to stand until the electrolyte temperature has fallen below 38° C (100° F) and the electrolyte level has remained constant for at least eight hours. Repeat the procedure outlined in paragraph 223−2.10.3.2. If the corrected specific gravity for every cell is within the limits specified, the adjustment of specific gravity is complete. Adjust any cell having a corrected specific gravity which falls outside the limits given in paragraph 223−5.3.4.11.

223−2.10.4 TEST DISCHARGES PRIOR TO INSTALLATION. The test discharge allows initial battery capacity to be determined. It also helps build up the battery capacity. Dry cells prepared for service at a shipyard or base shall be given at least one test discharge prior to installation. This discharge shall be given following the initial charge and adjustment of specific gravity (paragraph 223−2.10.3.2). The test discharge shall be conducted at the 6−hour or at the 10−hour rate.

223−2.10.4.1 Capacity. The manufacturer's instructions for putting cells into service outline a procedure for accelerating the development of full capacity. This procedure should be incorporated in the testing schedule.

223−2.10.4.2 Readings During Initial Test Discharges. Readings of total battery voltage, pilot cell voltage, temperature and specific gravity (corrected for temperature and electrolyte level, if applicable) shall be taken and recorded at the start of the test discharge and at each succeeding half hour. Similar readings of all cells shall be taken and recorded every hour after the first four hours, and, as the low voltage limit is approached, as often as necessary to ensure that no cell is discharged below the minimum final cell voltage (paragraph 223−3.5.4.1).

223−2.10.4.3 Initial Test Discharge. The discharge current is maintained constant at the proper discharge rate (paragraph 223−2.10.4) until either the voltage of the whole battery falls to the battery low−voltage limit or the voltage of any cell falls to the minimum final cell voltage, whichever occurs first. The discharge is then stopped. In order to determine whether the test discharge is satisfactory or not, refer to discharge characteristics on the curves and data plan for the battery and find the time of discharge at the 6− to 10−hour rate for an initial temperature equal to that of the battery at the start of the test discharge. If the measured time duration of the test discharge is equal to or greater than the 90% of figure obtained from the plan, the test discharge is satisfactory. See paragraph 223−3.5.4 for low voltage limits. If the initial rate is equal to the service rate, the time of discharge of a satisfactory battery is specified on the manufacturer's instructions for putting cells into service. (see paragraph 223−3.5.8 for initial and service rates)

223−2.10.5 EQUALIZING CHARGE PRIOR TO INSTALLATION. Following satisfactory completion of the initial test discharge, give the battery an equalizing charge returning 140−percent charge back (paragraph 223−3.5.8(b)); then, check the specific gravity of each cell, and adjust again, if necessary (paragraph 223−2.10.3.3).

223−2.10.6 ELECTROLYTE ANALYSIS PRIOR TO INSTALLATION. After completing the equalizing charge (paragraph 223−2.10.5), take approximately a 150 ml (or five ounce) sample of electrolyte from each pilot cell and forward it to a Government laboratory for analysis for impurities listed in Table 223−18. Replace the electrolyte removed with an equal volume of pure electrolyte of the same specific gravity.

If the electrolyte analysis indicates that the electrolyte is unsatisfactory, submit a report to NAVSEA giving the probable source of the impurities and the remedial action taken. This information shall also be entered in the battery record book.

223−2.10.7 REPORT AND PREPARATION RECORDS RETENTION. A report consisting of the following information shall be prepared and retained by the preparing activity for 7−1/2 years, thereafter, the report may be destroyed. NAVSEA may request copies of these records on a per case basis within the time periods stated, which represent the maximum possible battery age. The report shall:

a. Give the type and contract number of batteries and a brief, dated log listing principal events, with dates. Include any departures from prescribed instructions and the reason why these departures were necessary. It shall also include any pertinent comment or recommendations.

b. Present individual cell voltage and corrected specific gravity readings at end of the equalizing charge just prior to installation. This may be presented as a graph.

c. List cell numbers, as installed, with the manufacturer's serial number of each.

d. Give results of electrolyte analysis.

223−2.11 INSTALLATION OF CELLS IN SHIP

223−2.11.1 INSPECTION OF BATTERY AREA. Before installing the battery in the ship, ensure that the battery tank, battery−tank lining and woodwork are in proper condition to receive it. In some submarines, high−pressure air flasks are installed outboard of the battery tanks. These air flasks and their stowage are accessible for inspection only when the battery is out of the tank. Consequently, take advantage of this time to make necessary repairs. Inspect battery sumps and suction pipes for proper condition. Inspect entire ventilation system, including such items as lead ducts, sheet−metal sections, dampers, blower impellers and motors, and valves, and repair as necessary.

223−2.11.2 PREPARATION OF THE BATTERY TANK. Fit fillers or cribbing to tank sides and ends to take up any inequalities. The battery space must be square, plumb and dimensioned exactly as shown on the battery−layout drawing. All nonparaffin impregnated woodwork used in the battery tank should be well coated with approved acid−proof paint both before and after fitting.

223−2.11.3 REMOVAL OF CELLS FROM SHIPPING CRATES. Remove cells shipped wet from their shipping crates by removing shipping crate cover and loosening all tie rods. Ensure lifting devices are insulated to prevent short circuits when handling charged cells. Attach cell−lifting device to cell terminals and apply a slight tension to cell terminals only. Then attach lifting device to the cell and hoist cell from its shipping crate by a straight lift until cell is clear. Lifting devices are equipped with straps that hook under the cell bottom. Lifting devices and straps must be firmly tightened before cells are lifted by cell terminals.

223−2.11.3.1 Disposition of Shipping Crates. Contracts for new construction submarines generally provide for return of shipping crates to the preparing activity. Shipping crates will be returned in the knocked−down condition unless otherwise specified.

223−2.11.4 INSPECTION AND CELL TESTS PRIOR TO INSTALLATION. Additional tests and checks are needed before installing cells, as described in paragraphs 223−2.11.4.1 through 223−2.11.4.5.

223−2.11.4.1 Air Pressure Tests. To determine the integrity of the cover−to−liner seal, cells shall be subjected to seven kilopascals (kPa) [one pound per square inch, gauge (1 lb/in^{2}g)] of air pressure for one minute. Assembly activities shall conduct the following test procedures on all cells after assembly, following wet down, prior to installation and after installation in ship:

1. Install the test fitting in the flash arrester opening of the cover.

2. Attach air line with pressure gauge and air supply valve to test fitting on cell.

3. Open the air supply valve and pressurize cell to seven kilopascals (kPa) (one psig) and close the air supply valve. Cell shall show no loss of pressure for one minute. With no loss of pressure, cell has passed the air pressure test; proceed to step 7.

Troubleshooting

4. Bring pressure back to seven kPa (one psig) and allow the cell five minutes to reach equilibrium (maintain pressure during the equilibration time).

NOTE

> Equilibration time may be necessary to allow any air entrapped between the liner and the jar to escape through the secondary cover/jar seal.

5. Bring pressure to seven kPa (one psig) and check for a pressure drop for one minute. If no loss is experienced, the cell has passed the air pressure test and proceed to paragraph 7. If pressure drop is experienced, continue to next step.

6. With cell pressurized at seven kPa (one psig), check for leaks at cell cover fittings and at the jar/cover seal area. Leaks shall be determined by placing a non−ionic leak detecting solution or soap solution in this area.

a. Leaks at the cell cover fittings may be stopped by tightening the fittings as necessary.

NOTE

> If a cell is equipped with an air agitation system, the coupling nut MUST NOT be over−tightened.

If leaks persist at the cell cover fittings, the cell must be repaired and re−tested to ensure air tightness in accordance with step 3.

b. Leaks at the jar/cover seal areas of GUPPY I Mod C and TRIDENT cells must be repaired and re−tested to ensure air tightness in accordance with step 3. During installation of GUPPY I Mod E cells, if a cell is detected with a jar/cover seal leak, that cell is to be replaced with a spare and the defective cell marked for later repair.

7. The pressure shall be released from the cell, the test fitting removed and processing of that cell continued.

8. Upon completion of the pressure test, reinstall flash arrester on each cell (paragraph 223−2.11.4.2).

223−2.11.4.2 Sealing Flash Arresters. The effectiveness of a flash arrester dome depends upon its being the only path for explosive gas leaving the cell. Any bypass will reduce the value of the dome; a crack will reduce its effectiveness. Domes should, therefore, be visually inspected for cracks before installation. Flash arresters have an O−ring gasket to seal the assembly to the cell cover, which will give a gastight seal when tightly screwed by hand into the cell cover.

223−2.11.4.3 Dielectric Test for Leaky Jar/Liner Assembly. A dielectric test using 500 volts minimum shall be made on each cell just prior to lowering the cell into the submarine. Test procedure is as follows:

1. Use a tank about 50 mm (two inches) higher than the jar and large enough in area so that there will be at least 100 mm (four inches) clearance all around the jar when it is placed in the tank. The tank may be metal or wood. However, in the latter case, the tank should be provided with a metal grounding strip extending from the rim of the tank into the solution the tank is partly filled with.

2. Fill tank partly with water and add sufficient ammonia to make a dilute solution. Lower cell into tank slowly, particularly when testing the first cell, so as to ensure the water does not come over the top of the jar and onto the cover. The height of the water should be 25 mm (one inch) below the top of the jar when the cell is resting on the bottom of the tank. It will be necessary to add water, as well as ammonia, from time to time. When the outside air temperature is below 0° C (32° F), this test should be made indoors as near the time of installation as possible.

3. Detach lifting device. Using a 500 volt megohmmeter or 500 Vdc source and voltmeter obtain a reading between a cell terminal and the metal tank or grounding strip. The meter must indicate a resistance of at least 100 megohms or an equivalent voltage from the specific cell type (Figure 223−13).

4. If the reading is low, do not assume at once that a leak through the jar/liner assembly exists. Check the lead from the megohmmeter to the test probe to make sure that it is insulated everywhere. Wash and dry the entire cover and top edges of the jar to make sure that the reading is not due to surface leakage caused by moisture or high air humidity. If a low reading is still obtained, the cell has a leak. A leaky cell should be rejected.

5. After testing, wipe the cover and blow dry the outside of the cell with low−pressure air before installing it in the ship.

223−2.11.4.4 Service Opening Caps to be In Place. Before lowering the cells into the ship, all caps should be in place to prevent the entry of foreign matter during installation. Flash arresters are not installed at this time due to interference with the lifting device. A blanking cover with a threaded or tight friction fastening is substituted for the flash arrester. Coverage with masking tape or similar means is inadequate to provide the needed protection.

223−2.11.4.5 USS DOLPHIN Air Test of Water−cooling Channels. Cells having water−cooling channels shall be tested for integrity of the channels after the formation cycles by capping one end of the channel and applying 207 kPA (30 psig) air pressure at the other end, for at least one minute. No drop in pressure shall be permitted. Installing activities shall conduct this test on all cells prior to installation and after installation (paragraph 223−2.11.6.3).

223−2.11.5 INSTALLATION OF CELLS IN BATTERY TANK.

a. Location of the hatches and trim of the ship will usually determine at which end of the battery tank to start installing the battery. If the hatch is up by the bow, the first cell installed should be at the after

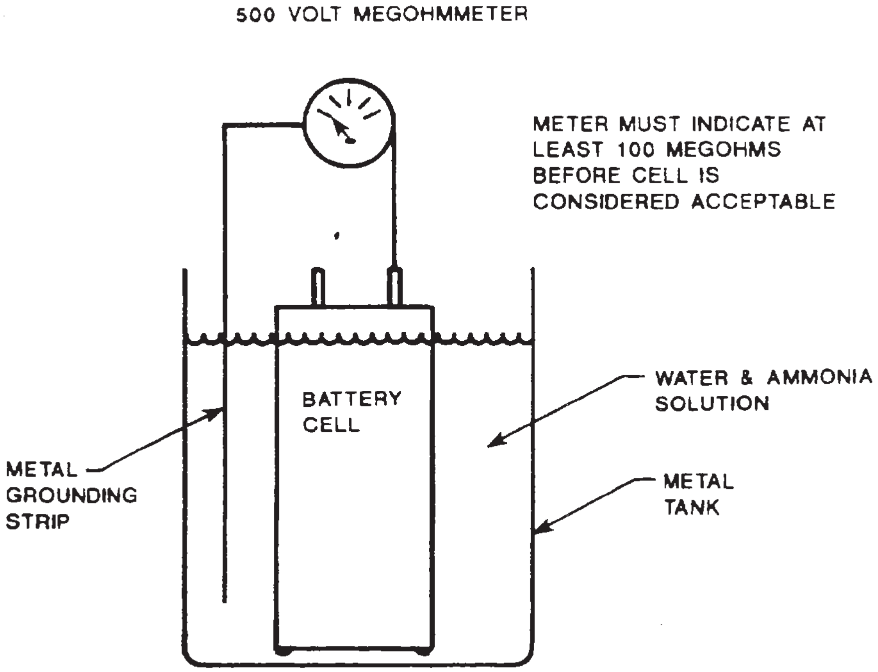


Figure 223−13. Dielectric Test Circuit

end of the tank, and vice versa, working toward the opposite end as the installation progresses. Battery renewals should duplicate the original installation unless modified by Ship Alteration (SHIPALT). To ensure exact duplication, the installation shall be made as shown on applicable ship's plans, except where obvious violations of approved practices are uncovered. This is of prime importance with respect to wedging and providing filler pieces over and around crib bolts, since improper wedging and cribbing can result in shifting of cells and leakage of electrolyte.

b. To aid in installation, several temporary wood spacers should be used for spacing a cell being installed from the cell or cells alongside which it is being placed. These spacers should be 64 mm (2−1/2 in.) wide and 0.8 mm (1/32 in.) thinner than a pair of wedges. About 150 mm (six in.) from the top, the spacer should be 20 mm (3/4 in.) thicker than its remaining length, so as to provide a stop which will rest on top of the jar wall. An easy way to accomplish this is to fasten to the spacer, by means of screws, a cleat 150 mm (six inches) long by 20 mm (3/4 in.) thick.

c. Spot each cell into position as accurately as possible, ensuring that the rubber tank lining is not damaged and avoiding accidental removal of the acid−resisting paint on the tanks. Before spotting the cell, hang the spacers by the cleats from the top corners of the cell or cells already in position, and push the new cell hard against the spacers.

d. Take care to ensure that outboard cells and cells alongside partitions or bulkheads are placed as close as possible against the filler or woodwork. Take precautions to ensure that all partitions are sufficiently braced before placing cells against them.

223−2.11.6 WEDGES AND WEDGE FILLER AND CRIBBING PREPARATION. Wedges are prepared and used as follows:

a. All wedges shall be constructed of maple, suitable hardwood or plastic (TRIDENT). In an emergency an equivalent hardwood may be used, but a softwood, such as spruce, should not be considered. When wedges are removed prior to lifting a cell, a wedge of softwood will be crushed between the jaws of the wedge puller and cause cell jars to break.

b. Wood wedges and any wood fillers and cribbing that might be used at the sides and ends of tanks and between rows of cells should be cut to approximate size and then impregnated with paraffin as follows:

1. Boil in a bath of melted paraffin wax at a temperature between 110° C and 180° C (about 230° F to 350° F) for at least 20 minutes.

2. Cool the bath, with the wood left in, until the paraffin is no longer liquid. This ensures maximum penetration of the wood by the paraffin.

3. Reheat the bath until it is hot enough to permit removing the wood. Remove wood and allow excess paraffin to drain off.

223−2.11.6.1 Placing Wedges. In many battery tanks, the layout provides that certain cells will be adjacent to each other without wedges between them. Refer to the shipbuilder’s plan showing the details of woodwork, and install the wedges as called for in this plan. Intercell connections will not fit if the cells are not properly arranged.

223−2.11.6.2 Driving the Wedges. When all the cells in one tank or compartment have been placed in position, the wedges will be at various heights above the jars. In driving the wedges, ensure that cell posts of adjacent cells line up properly and are the correct distance apart, so that the cell connectors will fit in place. Cell connectors shall not be bolted until wedging has been completed. In driving the wedges, proceed in the following manner:

a. Start with the highest wedges, driving them about 150 mm (six inches) at a time. If cells are installed while the ship is not evenly trimmed, the wedges between the cells spotted first will generally be the tightest. In this case, these wedges should be driven first on each round of driving.

b. All wedges should be driven home not more than 13 mm (1/2 in.) below the top of the cells or as far as they can be driven without risk of damage to the jars. If the tank and woodwork are built to prescribed dimensions, and if cells are carefully placed and not bulged or warped, the edges can normally be driven home without difficulty.

c. If wedges cannot be driven home without risk of damaging the jars, they should be allowed to stand overnight (or longer, if time permits). In most cases, they can then be driven home without difficulty. After several days of standing, if any of the wedges cannot be driven home, the portion extending above the tops of the jars should be cut off. In no case, however, shall a wedge be cut off more than one−fourth its total length.

WARNING

> Safety precautions per section 223−6.2.6.2 shall be observed. The procedures of that section shall be performed prior to bussing up the battery.

d. Wedges shall be cut off flush with cell jar provided they cannot be driven home. Precautions should be taken to protect battery terminals and jars. The blade of the saw used for wedge cut off should be no longer than the distance between the cell terminals; modifications should be made to the saw in order to comply. In addition, the saw handle and noncutting edge of the blade shall be insulated as necessary to protect personnel and battery cells. All wood chips, dust and shavings shall be thoroughly vacuumed from the battery well.

223−2.11.6.3 Air Pressure Tests After Installing Wedges. After placement and installation of wedges (paragraph 223−2.11.6.1) and prior to installation of connectors (paragraph 223−2.11.8), the cover−to−liner seal air−pressure test (paragraph 223−2.11.4.1 or 223−2.11.4.5) shall be repeated.

223−2.11.7 CLEANING CELL POSTS AND COVERS. Before installing cell connectors, wash the cell posts with a cloth dampened in baking soda solution that contains no more than 30 grams/litre of baking soda. Surfaces should then be brightened with fine sandpaper. Inasmuch as the protective lead coating is only 50 micrometers (two mils) thick, take care not to lay bare the copper surface. Wipe off the tops of the cell covers with a cloth dampened in baking soda, ensuring that the solution does not get into the cells or battery tank. Wipe clean with a cloth dampened with DI water.

223−2.11.8 INSTALLING CONNECTORS. Lead−plated or stainless steel (316 stainless only) nuts, bolts and washers are used. Stainless steel hardware is used in all installations made after January 1980. When stainless steel is used, a 316 stainless steel locknut is used. The locknut is coated with molybdenum disulfide (Moly Coat), a dry−film lubricant, which must not be removed. The locknut requires a 14 newton−meter (Nm) [120 inch−pound (in−lb)] turn−on torque, and will overheat and seize if the lubricant is removed. When lead−coated hardware is used, apply a heavy mineral grease (DOD−G−24508, Grease, High Performance, Multipurpose) freely to nuts and bolts. Regardless of hardware used, grease terminal contact surfaces. Bolt connections in place according to the battery plan. Never strain the terminal in making the connection. Hammering terminals is prohibited because it can impair the bond between the lead casing and the copper insert in the cell bus bars. Connectors are manufactured with holes of a diameter greater than the diameter of the bolts. If a connector does not fit easily, use one with a larger distance between holes. If the connector still does not fit, it may be elongated to a maximum of 16 mm (5/8 in.) in width by 25 mm (one inch) in length. Coat the bare copper surface freely with grease to prevent corrosion.

223−2.11.8.1 Tightening Connectors. Torque nuts and bolts to 57−62 Nm (500−550 in−lb) using the specially designed and insulated torque wrench specified in section 223−1.9.18. The handle has three machined grooves to identify the area to be gripped by the user when applying torque. The wrench is an audible breakaway type. It will allow the end of the handle to free−travel approximately 13 mm

(1/2 in.) when 59.5 + 3 Nm (525 + 25 in−lb) of torque is reached. To continue to tighten after the handle has broken away will cause overtorquing of the bolt. The wrench may be used to loosen nuts and bolts, but the torque feature is accurate only for tightening in the clockwise direction. Included with the wrench are a 20 mm (3/4 in.) and 21 mm (13/16 in.) six−point impact socket to be used only for battery maintenance and only on nuts and bolts of proper size. Proper torque values are achieved only when proper−sized tools are used and only if torque is applied on the nut. Do not apply torque on bolt heads. The 21 mm (13/16 in.) socket is not needed when stainless steel hardware is installed. If the special torque wrench is not available, use a standard breakaway type torque wrench insulated in accordance with section 223−2.11.10 to a minimum thickness of three mm (1/8 in.). Insulate the work area with a rubber sheet or mat, three mm to six mm (1/8 in. to 1/4 in.) in thickness, to prevent contact with cell terminals and bus bars at a different electrical potential if the torque wrench slips off during the torquing operation. Wipe off excess grease around the connections after nuts and bolts have been tightened. When stainless steel hardware is used, it may become warm to the touch during installation. In all cases, stainless steel hardware shall be retorqued after a period of at least one hour from initial installation to allow for expansion and/or contraction of stainless hardware used due to temperature change from outside the battery well to the inside.

223−2.11.9 CONNECTING VOLTMETER LEADS. The individual cell voltmeter leads shall be made up in such a way that they can be connected to fuses in in−line fuse holders or boxes. Primarily in−line arrangements with the fuse holder under the plastisol boot covering the terminal and the electrical connection being made directly at the terminal nut or bolt are used. When fuse boxes are used, they are mounted on the intercell connectors, except for the voltmeter lead at the positive end of each battery, which shall be connected to a fuse box mounted on the positive battery terminal. Voltmeter leads shall be assembled into a cable and supported so as to be clear of all parts of the cell and intercell connectors. The cable shall be secured to prevent sagging or motion that might cause it to fray.

223−2.11.10 ELECTRICAL INSULATION IN THE BATTERY TANK. Air spacing between bus bars of opposite polarity and from bus bars to ground shall be not less than 25 mm (one inch) and as much larger as practical. Creepage distance between bus bars of opposite polarity and from bus bars to ground shall be not less than 75 mm (three inches) and as much larger as practical. Phenolic material shall not be used as an insulator or as a support for bus bars due to the possible risk of a release of the acidic and poisonous compound phenol. Glass melamine or glass silicone should be used throughout for insulating. The space between intercell connecting bolts and nuts and bus bars at a different electrical potential or ground shall be not less than 75 mm (three inches) to permit safe use of torque wrenches.

223−2.11.10.1 Taping of Bus Bars. All bus bars in battery tanks, except intercell connectors, should be wrapped with at least two layers of half−lapped glass tape. In all cases where buses of opposite polarity pass within 75 mm (three inches) of each other or within 75 mm (three inches) of ground (except intercell connectors), two layers of half−lapped mica tape should be applied under the glass tape. Such mica tape should extend approximately 150 mm (six inches) beyond where the buses are in proximity to each other or to ground. Mica or glass tape shall not be less than 175 micrometer (seven mils) thick and each layer should be well coated with approved insulating varnish. Bus bars should be taped as follows:

a. Where both mica and glass tape are required, coat the bus bar with an approved insulating varnish and, while it is still tacky, apply a layer of half−lapped mica tape. Apply a second coat of varnish and, while still tacky, wrap a second layer of half−lapped mica tape. Repeat the application of varnish as before, and apply a layer of glass tape, half−lapped. Repeat the application of varnish and wrap on a second layer of glass tape, half−lapped. Coat the finished taping completely with the insulating varnish.

b. If mica tape is not required, apply two layers of glass tape in sequence, interposing a coating of insulating varnish before each layer is wrapped on, and half−lapping each layer of tape.

223−2.11.10.2 Tape. Mica tape (General Electric Co. type No. 1604−reinforced mica tape) 175 micrometers (seven mils) thick, 25 mm (one inch) wide or equivalent may be used. Glass tape in accordance with MIL−Y−1140, class C, 175 to 250 micrometers (7 to 10 mils) thick, 38 mm (1−1/2 in.) wide or equivalent may be used. Silicone varnished glass tape, 375 micrometers (15 mils), in accordance with MIL−I−17205, Insulation Cloth and Tape, Electrical, Glass Fiber, Varnished may also be used.

223−2.11.10.3 Use of Plastic Coating Compounds. In lieu of taping, plastisol compound in accordance with MIL−I−15265 or MIL−P−20689 to a thickness of 1.6 mm (1/15 in.) may be used. Bolted connections and that area of the bus bar making contact with the individual cell voltage (ICV) fuse−box mounting hardware cannot be dipped in plastisol. They must be covered with either a removable cap or boot made of varnish−impregnated glass cloth that complies with MIL−I−17205 or a slip−on premolded plastisol cap or boot that complies with MIL−I−15265 (MIL−STD−2003). Bolted connections on battery quick−opening disconnects are not insulated.

223−2.11.10.4 Heat Reactive Tubing. Nonrigid, thin−walled, heat reactive tubing in accordance with MIL−I−15265, type T, is required. This tubing may be readily slipped over the bus bar section and by application of heat will contract to form an insulating layer of uniform wall thickness over the bus bar. The tubing will completely conform after heating 10 minutes at 150° C (300° F). Reaction time is longer for lower temperatures; however, application should not be attempted at temperatures below 120° C (250° F). Application of heat by means of a heat lamp is considered satisfactory.

223−2.11.11 INDIVIDUAL CELL VOLTAGE (ICV) WIRING. The battery individual voltage measurement system conductors, wireways, or ducts shall be located on the side of the cells and shall be arranged so that they will not cross above any energized part of the battery. Where they cross below energized parts, the electrical creepage and clearance distance shall be equal to or greater than those specified in MIL−E−917, Electrical Power Equipment, Basic Requirements. Fuse boxes or in−line fuse holders shall be mounted on the intercell connectors adjacent to the wireway or duct so as to minimize the length of the conductors.

223−2.11.12 INDIVIDUAL CELL VOLTAGE (ICV) FUSE. Each fuse box or in−line fuse holder contains a fuse rated at 500V/3AS that provides protection in the event of a short circuit: at the ICV monitoring panel, between ICV conductors, or between ICV conductors and bus bars.

223−2.11.13 INSTALLATION OF QUICK OPENING DISCONNECTS. To satisfy the requirements for rapid access, quick opening disconnects are installed in the battery well near the electrical ends of the battery, above the cell tops. The disconnects are usually operated with a special wrench from inside the battery well. In some installations, operation is through linkage from a station outside the battery well. In either case, the disconnects shall be installed above the level of the cell tops to permit operating personnel in the battery well to insert the wrench specified in MS17832, Operating Wrench, Bus Disconnect Symbol 1485. This arrangement allows quick operation and reliable inspection of bus bar alignment and contact surfaces.

NOTE

An inspection shall follow installation of quick opening disconnects and any evolution that disturbs the connections at the electrical ends of the battery to determine satisfactory bus bar alignment and to ensure a minimum of 90 percent line contact. This may be verified by obtaining an impression using carbon and white paper tightened between contacts.

223−2.12 PROCEDURES AND TESTS AFTER INSTALLING BATTERY

223−2.12.1 VENTILATION SYSTEM AND PRESSURE TESTS. Accomplish air test as follows:

1. Verify supply and exhaust plenums are in accordance with ventilation plans.

2. Check operation of recirculating fans in battery tanks (not applicable to all installations).

3. Check battery exhaust fan(s) for proper rotation.

4. Conduct air pressure test in accordance with paragraph 223−2.11.4.1.

223−2.12.2 CHARGE AT END OF BATTERY INSTALLATION. During new construction, all work in connection with the battery installation shall be completed so that the charges prescribed by paragraph 223−3.3 may be given at the proper intervals. As soon as possible after the battery has been installed and the battery compartment been ventilation system airflow rates and air distribution tests have been conducted (paragraphs 223−2.12.1, 223−4.6.5 and 223−4.6.6), a charge should be given.

SECTION 3.
OPERATION

223−3.1 GENERAL

Normal underway and in−port operations are addressed in paragraphs 223−3.1.2 through 223−3.5.16. Battery operation during periods of new construction, overhaul and extended availability, are addressed in paragraph 223−3.6.

223−3.1.1 CONFLICTS IN DOCUMENTATION. In the event of conflict among battery procedures, maintenance manuals, safety precautions, testing or other maintenance matters, NAVSEA should be notified of the conflict. NAVSEA will recommend the correct action to be taken. If, however, an emergency exists where NAVSEA approval or recommendation is not available right away, the following documentation order of precedence shall be used:

1. Maintenance Requirement Cards (MRC)
2. Manufacturer's Battery Technical Manual
3. **Naval Ships' Technical Manual, (NSTM) Chapter 223, Submarine Storage Batteries Lead Acid Batteries**.

NOTE

> This order of precedence should be used only in emergency conditions and only with the commanding officer's approval. NAVSEA should be notified of such an emergency condition and any deviations from normal operating procedures as soon as possible.

223−3.1.2 CHARGE AND DISCHARGE. This section deals specifically with battery charging and discharging operations in actual use on ships. Certain general principles applicable to charge and discharge are discussed in paragraphs 223−3.1.3 through 223−3.1.11.

223−3.1.3 IMPORTANCE OF BATTERY VENTILATION. Explosive and noxious gases are evolved from a lead acid storage battery cell. Ventilation removes these gases and prevents their accumulation in sufficient concentration to form an explosive or noxious atmosphere at any point in the battery ventilation system. Improper battery ventilation creates an explosion hazard and may impair the health of personnel. The subject of ventilation is covered in Section 4.

223−3.1.4 SAFETY. Precautions and safety are discussed extensively in Section 9. Safety of personnel must be maintained during all battery operations. Special instruments are provided to detect development of certain unsafe conditions. However, strict adherence to specified procedures by qualified operators is the only method of ensuring safety for all personnel.

223−3.1.4.1 Personnel Requirements. Specific requirements apply to the qualifications of personnel responsible for the supervision and operation of the battery (paragraphs 223−3.4.1.1 and 223−3.4.1.2).

223−3.1.4.2 Ground Resistance. The greater the resistance to ground, the less the danger of electric shock if a person makes contact simultaneously with ground and a live conductor. A battery ground resistance of 500K ohms or greater shall be maintained. Resistances between 100K and 500K ohms require a thorough battery well cleaning. Any resistance below 100K ohms is considered unacceptable. Grounds should be immediately located and cleared. A proper battery well maintenance program will be capable of maintaining the ground resistance value of 500K ohms or larger. In addition, ground resistance measurements should be made before any work is performed that involves touching a cell terminal. If the work involves disconnecting cells, be especially careful to insulate all parts of the body from ground by using a rubber sheet over parts of the ship's structure with which contact might be made. In this way, even if the battery should be accidentally grounded during the working period, it will not be likely that the body will simultaneously contact the live terminal ground.

223−3.1.5 BATTERY COOLING SYSTEMS. Temperature control for batteries is attained through the battery cooling system. Lead−calcium batteries are air−cooled, which counters the effects of operation in warm water which generally imposes difficulties caused by high battery temperatures. Battery ventilation systems are designed to furnish only sufficient airflow to dilute the hydrogen to a concentration below three percent during charges, and do not provide sufficient cooling to prevent battery electrolyte temperatures in excess of 54°C (130°F) under all operating conditions. The cooling produced by ventilation is mainly derived from the evaporation of water from the electrolyte. For the procedures recommended when the temperature during charge reaches 54 degrees C (130°F), see paragraph 223−3.2.12. Consideration regarding high temperature during discharge is given in paragraph 223−3.5.10. USS DOLPHIN maintains a water−cooling system for its lead−antimony batteries; refer to USS DOLPHIN battery technical manual and ship information book.

223−3.1.6 SPECIFIC GRAVITY MEASUREMENTS AND CORRECTIONS. The following information describes the measurement and correction requirements and procedures for batteries.

223−3.1.6.1 Measurements. The specific gravity of the electrolyte is measured with a floating hydrometer which is weighted at one end. The depth of immersion of the instrument depends upon the specific gravity of the liquid in which it floats. Hydrometer readings must be corrected for the temperature of electrolyte when the readings are to be used as a measure of the state of charge, since they depend upon three factors, of which only the first furnishes a direct measure of the state of charge. These factors are:

a. the mass of sulfuric acid in the electrolyte

b. the volume of electrolyte or height of electrolyte in the cell.

c. the temperature of the electrolyte.

223−3.1.6.2 Correction for Temperature. Hydrometers for Naval use are calibrated to read correctly when the electrolyte temperature is 26.7°C (80°F). To correct for this temperature, add 0.001 to the hydrometer reading for each 1.7° Celsius (three degrees Fahrenheit) the electrolyte temperature exceeds 26.7°C (80°F) and subtract 0.001 from the hydrometer reading for each 1.7° Celsius (three degrees Fahrenheit) the electrolyte temperature is below 26.7°C (80°F) as shown in Table 223−9.

Table 223−9. SPECIFIC GRAVITY TEMPERATURE CORRECTION

Electrolyte temperature (°C)	Electrolyte temperature (°F)	Specific gravity correction	Electrolyte temperature (°C)	Electrolyte temperature (°F)	Specific gravity correction
10	50	-0.010	32.2	90	+0.003
15.6	60	-0.007	37.8	100	+0.007
21.1	70	-0.003	43.3	110	+0.010
26.7	80	-0.000	48.9	120	+0.013

223−3.1.7 INTERPRETATION OF CORRECTED SPECIFIC GRAVITY. Hydrometer readings give the uncorrected specific gravity of the electrolyte above the plates. When the corrections for temperature of electrolyte are applied, the corrected specific gravity obtained is still that of the electrolyte above the plates. If the electrolyte is not uniformly mixed, the corrected specific gravity does not represent the true state of charge or discharge.

223−3.1.7.1 During Charge. When the cell is on charge, and the air agitation system is not operating, the electrolyte is not uniformly mixed until the cell has been gassing freely for some time. The corrected specific gravity of the electrolyte above the plates is lower than the average for the whole body of electrolyte until that time. This stratification is particularly true with cells having glass mat retainers that restrict acid circulation. In this case, the cell is more fully charged than is indicated by the corrected specific gravity.

223−3.1.7.2 During Discharge. When the cell is on discharge, without air agitation, the electrolyte tends to mix by natural diffusion. However, this takes time and, consequently, the corrected specific gravity of the electrolyte above the plates is higher than the average for the whole body of electrolyte. In this case, the cell is more completely discharged than is indicated by the corrected specific gravity. The amount of error is small for discharge rates below 400 amperes (A).

223−3.1.8 RELATION BETWEEN AMPERE−HOUR (AH) OUTPUT AND DROP IN SPECIFIC GRAVITY. For the battery types now in use, the theoretical values of the ampere−hours per point (Ah/pt) are given in Table 223−1 (paragraph 223−1.5.5.

a. As explained in paragraph 223−1.5.2 3.66 grams (0.129 ounces) of sulfuric acid are used up per Ah of discharge through the battery. Tables on the density of sulfuric acid solutions show that a drop in specific gravity at 26.7°C (80F) of 0.001 (one point) corresponds to a decrease in acid content of 1.7185 grams per liter (0.229 ounces per gallon). Therefore, if the volume of the electrolyte is one liter, a drop in specific gravity of 0.001 corresponds to 1.7185/3.66 = 0.4696 Ah (and for one gallon, 0.229/0.129 = 1.775 Ah) passing through the cell. Consequently, for any cell, the Ah/pt drop in specific gravity is 0.4696 times the number of liters of electrolyte (or 1.775 times the number of gallons).

b. The observed value of Ah/pt drop on discharge is usually greater than the theoretical value. This is because specific gravity decreases faster in the electrolyte next to the plates than in the electrolyte above the plates. The observed specific gravity drop is based on measurement of the specific gravity of electrolyte drawn from above the plates. Consequently, the observed specific gravity drop during the discharge is less than the true or average value for the entire electrolyte. For hourly rates equal to or longer than the 20−hour rate, the difference is negligible. For the 10−hour rate the difference is about five percent. For the 1−hour rate, however, the difference may be 50 percent, so that the Ah per observed specific gravity drop is twice the theoretical. (see paragraph 223−3.5.13.3 for output calculation)

223−3.1.9 INTERPRETATION OF VOLTAGE READINGS. The voltage of a lead acid cell depends upon: whether it is on charge or discharge; the current flowing through the cell; the specific gravity, temperature and purity of the electrolyte; the age of the battery and the condition of the plates.

a. Certain voltages signal the end of charge; and others the end of discharge. Although the open circuit voltages reflect the relative state of charge of cells, they cannot give a reliable indication of the battery capacity. Only end of charge (or end of discharge) voltages are a significant indication of the battery capacity. Low voltage on both charge and discharge may indicate excessive self−discharge (paragraph 223−6.2).

b. For the effect of sulfation on voltage, see paragraph 223−6.4.4.2. A charge voltage, at the specified finishing rate, above 2.65 volts per cell at 26.7°C (80°F), generally indicates a healthy condition of the negative active material and an absence of contaminants that affect the negative plates (paragraph 223−6.5.3). The steady state current at the specified voltage on charge serves to indicate when the charge is complete. The voltage on discharge serves to indicate when the discharge is complete. Voltage does not furnish a reliable indication of the state of charge or discharge for conditions intermediate between full charge and complete discharge.

c. The end of battery discharge is determined by voltages that are not corrected for temperature even though the charge voltages are corrected to 26.7°C (80°F). The uncorrected end of charge voltage must be observed to ensure that it does not exceed 355 volts. Although a voltage higher than 355 volts will not harm the battery, other equipment on the battery bus having individual maximum voltages of 355 volts may be damaged.

223−3.1.10 ELECTRICAL CYCLE. An electrical cycle for a submarine storage battery consists of a discharge from the fully charged condition to the low voltage limit for the rate of the discharge used, together with the following charge which brings the battery back to the condition that existed at the beginning of the discharge.

223−3.1.11 EQUIVALENT CYCLES AND COMPUTATION. Under service conditions, battery operation will not normally follow strict electrical cycles. For the purpose of computing battery life in terms of use, an equivalent (standard) cycle is used, arbitrarily fixed at 5000 for GUPPY I Mod C, 6500 for GUPPY I Mod E and 10,000 for TRIDENT in Ah of charge. This is approximately equal to the charge required after a discharge resulting in a drop in electrolyte specific gravity of 100 points (paragraphs 223−1.10.2 and 223−5.1.2.3).

223−3.2 CHARGING

223−3.2.1 DEFINITION OF CHARGE. The general definition of charge is given in paragraph 223−1.5:

a. A battery is receiving a charge only when the electric current converts active material that can later deliver electrical energy. Therefore, even though current may pass through the cell in the charging direction, unless it converts active material it is not a charging current. For example, if the cell is internally shorted, the current flowing through the short circuit produces heat only. If 300 amperes are going into the cell in the charging direction and 50 amperes are being bypassed through a short circuit, then only 250 amperes can be taken as the charging current. Another example: if the current produces gassing, in addition to formation of active material, then the current used to form gas must be subtracted from the total current to obtain the net charging current. As cells become fully charged near the end of an equalizing charge, practically all the current input is wasted in forming gas.

b. The definition of charge in paragraph 223−1.5 is more theoretical than practical. For one thing, the gassing current, even though it forms no active material, is of vital importance in achieving a full battery charge. It is also important with regard to safety since the hydrogen evolved is proportional to the gassing current. For submarine battery operation, therefore, a battery is to be considered on charge whenever electrical energy is being put into it whether active material is being converted or not.

c. For practical purposes, operational charges are classified as normal charge (defined in paragraph 223−3.2.7), overcharge (several types, defined in paragraph 223−3.2.8) and undercharge (or partial charge defined in paragraph 223−3.2.9).

223−3.2.2 IMPORTANCE OF PROPER CHARGING. Proper charging is the most important factor in determining the life and performance of a storage battery. The instructions contained in this NSTM chapter shall be observed as closely as operating conditions permit to ensure proper battery charging.

223−3.2.3 VENTILATION DURING CHARGE. Batteries shall be ventilated during charge in accordance with Section 4. Failure to properly ventilate creates an extremely hazardous condition and may result in a serious hydrogen fire or explosion.

CAUTION

Stop the charge immediately if the ventilation becomes impaired by blower failure or any other reason while a charge is in progress.

223−3.2.4 USE OF FLAME−PRODUCING APPARATUS PROHIBITED DURING CHARGE. When charging batteries, observe the following precautionary measures: (For charges conducted at dockside, certain exceptions are specified in paragraph 223−9.2.10.)

a. Use of blow torches, welding equipment or the like shall not be allowed in the ship during a charge or for 20 minutes after charge completion. Sparking of electrical apparatus shall not be allowed within the battery tank.

b. Lighted matches, cigarettes or pipes shall not be allowed within a battery tank or in the areas adjacent to the battery tank at any time during charge.

223−3.2.5 TEMPERATURE−VOLTAGE−GASSING (TVG) CURVE/TABLE. The TVG curve (Figure 223−14) is a plot of cell temperature versus cell voltage and may be found on the

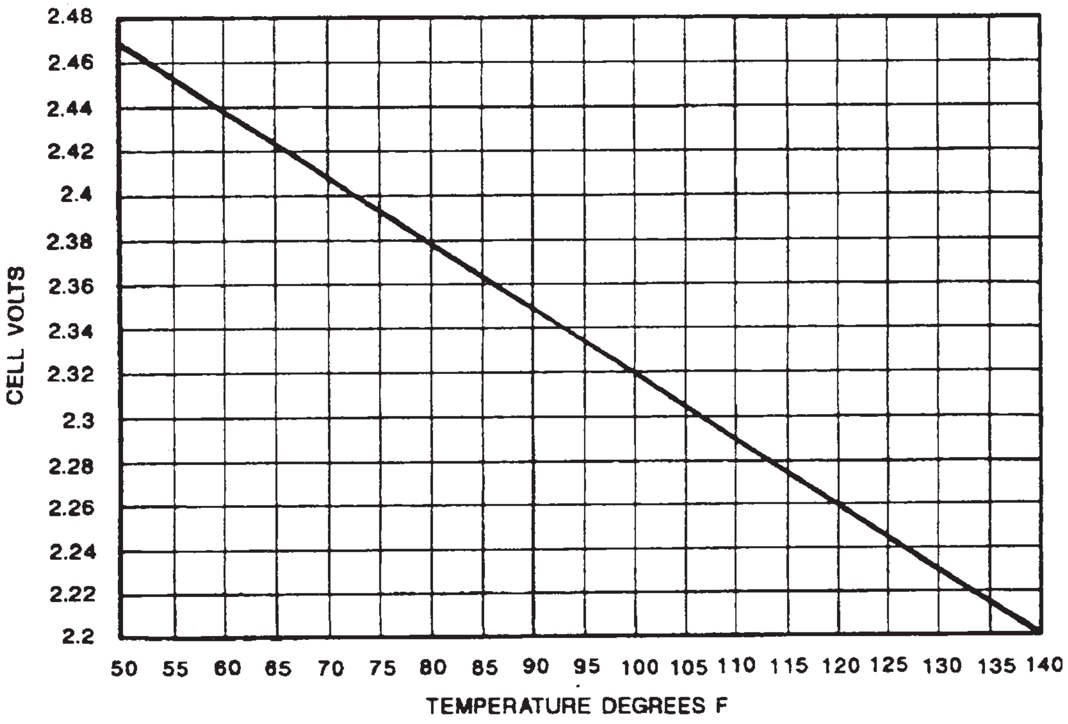


Figure 223−14. Individual Cell Temperature-Voltage-Gassing (TVG) Curve

manufacturer's curves and data plan for each battery type. The curve is used to determine the high−voltage limit, as determined by the average pilot cell temperature, before starting any charge. The voltage shown for each temperature is such that, when the voltage is corrected to 26.7°C (80°F) in accordance with paragraph 223−3.2.10, the result is a corrected voltage of 2.38 volts per cell. The curve is based on past experience which shows that at any charging rate above the finishing rate, the voltage corrected to 26.7°C (80°F) may be allowed to reach 2.38 volts per cell without injury to the battery. The curve is given by the equation:

$$V_c = 2.62 - [0.003(T_c)]$$

Where: V_c = cell voltage

T_c = cell temperature (degrees F)

As long as the cell voltage does not exceed this value, the minimal gassing that occurs is desirable and necessary whatever the charging current may be. But once this voltage or the approved finishing rate (paragraph 223−3.2.6.3) is exceeded, gassing proceeds at an excessive rate. Consequently, when the cell voltage, correct to 26.7°C (80°F), comes up to 2.38 volts, the charging current must be reduced until either cell voltage is less than the voltage limit shown by the TVG curve − consequently less than 2.38 volts when corrected to 26.7°C (80°F), − or the charging current is not greater than the finishing rate. Table 223−10 is known as the temperature−voltage−gassing table. This table is used to determine the TVG value for the ambient temperature and number of cells in a specific battery configuration; Figure 223−15 combines the values of the table into a plot. The values in the table

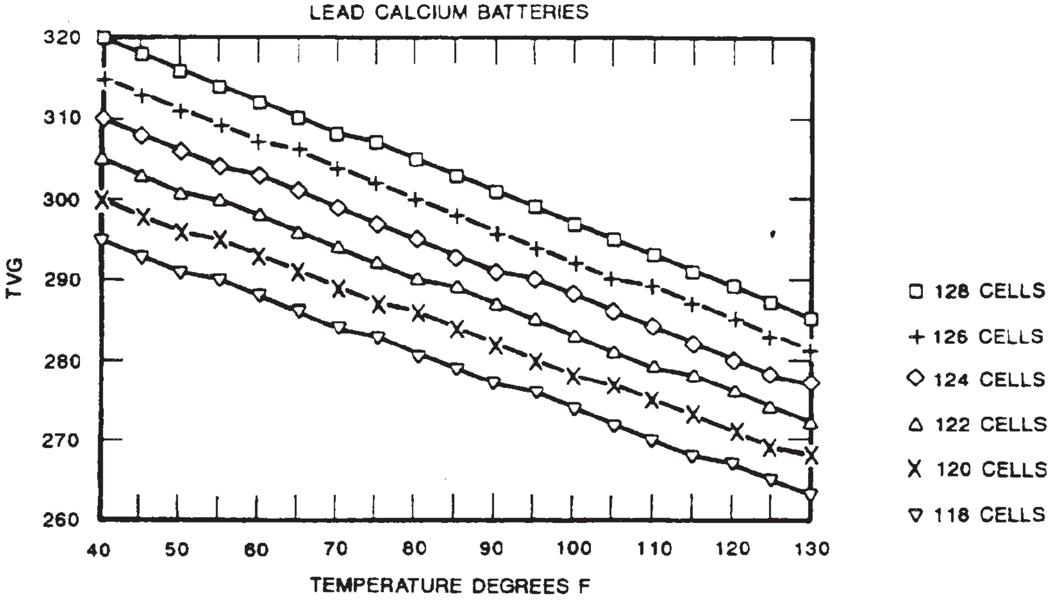


Figure 223−15. Temperature-Voltage-Gassing Table Plots

display the voltages for a battery at which the charge efficiencies decrease and where an increase in gas/heat generation may occur. The formula used to calculate the values within the table is as follows:

$$TVG = [2.62 - (0.003(T_c))]n$$

Where: T_c = average pilot cell temperature (degrees F) at the beginning of the charge operation

n = the number of individual cells within the battery configuration

NOTE: Table 223−10, Figure 223−15, and the formula above are valid for GUPPY I Mod C, Mod E and TRIDENT configurations.

223−3.2.6 CHARGING RATES. Except for the finishing rate, which should be maintained at the specified value (paragraph 223−3.2.6.3), the selection of charging rates is arbitrary as long as the TVG value is not exceeded. High charging rates will reduce the time of charge if the heat produced can be handled.

223−3.2.6.1 Limitations on Charging Rate. A storage battery may be charged at any rate within the capacity of the generators and cables, subject to the following limitations:

a. The electrolyte temperature limitation of section 223−3.2.12 should be maintained. Additional procedures for operation during high temperature periods are located in section 223−3.5.10.

b. Ampere−hour Rule: The initial charging current, if greater than the approved finishing rate, is set equal to the value of Ah previously discharged and is

Table 223−10. TEMPERATURE-VOLTAGE-GASSING (TVG) TABLE, LEAD CALCIUM

Temperature degrees F	Number of cells in the battery										
	128	127	126	125	124	123	122	121	120	119	118
40	320	318	315	313	310	308	305	303	300	298	295
45	318	316	313	311	308	306	303	301	298	296	293
50	316	314	311	309	306	304	301	299	296	294	291
55	314	312	309	307	304	302	300	297	295	292	290
60	312	310	307	305	303	300	298	295	293	290	288
65	310	308	306	303	301	298	296	293	291	289	286
70	308	306	304	301	299	296	294	292	289	287	284
75	307	304	302	299	297	295	292	290	287	285	283
80	305	302	300	298	295	293	290	288	286	283	281
85	303	300	298	296	293	291	289	286	284	281	279
90	301	298	296	294	291	289	287	284	282	280	277
95	299	297	294	292	290	287	285	283	280	278	276
100	297	295	292	290	288	285	283	281	278	276	274
105	295	293	290	288	286	284	281	279	277	274	272
110	293	291	289	286	284	282	279	277	275	273	270
115	291	289	287	284	282	280	278	275	273	271	268
120	289	287	285	283	280	278	276	273	271	269	267
125	287	285	283	281	278	276	274	272	269	267	265
130	285	283	281	279	277	274	272	270	268	265	263

then increased to obtain a battery voltage equal to the voltage limit specified on the TVG curve (paragraph 223−3.2.6). In other words if the battery was previously discharged at 2000 Ah then the initial charging current should be established at 2000 amperes. Use the finishing rate as this value if there was no previous discharge or if the battery is brand new and charged.

c. During a charge, when the charging current is greater than the approved finishing rate, cell TVG is shown in figure Figure 223−14. The battery voltage at any electrolyte temperature must not exceed the voltage limit shown for that temperature on the TVG curve (Figure 223−15).

223−3.2.6.2 Charging Rates to be Used. A storage battery shall be charged at rates specified in the following paragraphs:

a. Battery−charging rates shall be those meeting the requirements of paragraph 223−3.2.6. When charging by the modified constant potential method of paragraph 223−3.3.5.2, the rates existing will result from keeping the voltage at the TVG curve. The charge will be completed at the finishing rate without reference to the TVG curve.

b. There is a possibility under some operating conditions that one or more rates prescribed cannot be used because the resulting voltage is at or above TVG. If so, use a lower rate, but not below the finishing rate. For example, if the charging rate is cut from the 800 ampere rate to the 600 ampere rate and the voltage at the 600 amperes rate is at or above TVG, use the next lower rate.

c. Do not use finishing rates lower than the approved values specified on the curves and data plan except as specifically approved by the Naval Sea Systems Command (NAVSEA). Persistent use of low finishing rates will affect the negative plates and cause self−discharge and hydrogen evolution to increase much more rapidly with battery age than if the specified rates were used on every charge.

223−3.2.6.3 Finishing Rate. The finishing rate is the rate specified on the curve and data sheet in the manufacturer's service manual and used for the completion of a charge after the battery voltage reaches the limit set by the TVG curve (paragraph 223−3.2.5).

223−3.2.7 NORMAL CHARGE. A normal charge is a routine charge given during ordinary cyclic operation to restore a partially discharged battery to a substantially fully charged condition. The conditions that a normal charge must satisfy differ with the type of cell. The approved manufacturer's instructions should be consulted to determine these conditions for the type of battery installed in the submarine.

223−3.2.8 OVERCHARGE TYPES. An overcharge is any charge that is continued beyond the requirements for a normal charge, usually for specific reasons. The various types of overcharge used are described in the following paragraphs:

a. Normal−plus−one Charge. A normal−plus−one (N+1) charge is a normal charge that is extended for one hour at the finishing rate. Normal−plus−one charges may be used in lieu of normal charges when conducted in accordance with the manufacturer's service manual as approved by NAVSEA.

b. Equalizing Charge. An equalizing charge is a normal charge followed by an extended charge at the finishing rate, given periodically to ensure that all the sulfate is driven from the plates and that all the cells are restored to a uniform, maximum capacity. The conditions that an equalizing charge must satisfy differ with the type of cell. The approved manufacturer's instructions should be consulted to determine these conditions for the type of battery installed in the submarine. Equalizing charges are given approximately every 27−33 days. When operating conditions do not permit regular equalizing charges to be scheduled, an equivalent overcharge may be given as follows:

1. At seven day intervals following the last equalizing charge, extend the normal charge by one hour (section 223−3.2.8, paragraph a). If impractical to do this on the seventh day, do it on the eight or later day, extending the period of overcharging proportionately; that is, nine minutes per day.

2. On return to the base, an equalizing charge should be conducted as soon as possible.

3. During the stay at the base, the battery should be maintained in accordance with paragraphs 223−3.6 and 223−5.1.2.9.

4. After three equalizing charges have been conducted to establish a trend in overall individual cell readings, ship's force should carefully ensure pilot cells are representative of the battery as a whole, taking into account (per paragraph 223−5.1.2.1) temperature differences which exist in the battery.

c. Freshening charge. A freshening charge is a charge given to restore the fully charged condition of an idle battery that has lost part of its capacity by self−discharge. A freshening charge is conducted in accordance with the manufacturer's instructions. Freshening charges during storage prior to installation of lead−calcium grid batteries are conducted in accordance with paragraph 223−2.7. After installation of lead−calcium grid batteries, the equalizing charge routine (section 223−3.2.8, paragraph b) is followed in lieu of the freshening charge procedure.

d. Trickle−charge. A trickle−charge is a continuous charge conducted at a rate just sufficient to overcome the internal self−discharge of the battery. The term trickle−charge is also loosely applied to a low−rate, continuous charge at a current that is greater than required to overcome losses, but not great enough to cause active gassing of a fully charged battery. It is also associated with floating when the current flows under constant potential (section 223−3.2.8, paragraph f). Both forms of trickle−charging are considered undesirable, because the trickle rate necessary just to balance internal losses is very difficult to establish. Errors in setting the rate will result in undercharging or overcharging, which could result in a loss of capacity. For lead−calcium grid batteries, a low−rate trickle−charge is specifically forbidden as it results in capacity loss. NOTE: For lead−antimony grid batteries (USS DOLPHIN) low−rate charging at high voltages is injurious to the positive grids as well as the negative active material. Therefore, when a lead−antimony grid battery is fully charged and a trickle charge is necessary, the rate should be set between five and 10 amperes. When in doubt of meter accuracy, set the trickle rate at 10 amperes.

e. Floating for Calcium−grid Batteries. Float charging is not recommended for calcium−grid batteries. It can be used under limited circumstances. For example, when the ship is operating in an area where physical ability to surface is limited and full battery capacity must be ensured (for example, when operating under ice).

f. Float charging procedures for USS DOLPHIN should be followed according to USS DOLPHIN description and operation maintenance technical manual.

NOTE

Consult the manufacturer's service manual for detailed instructions concerning the float charge.

223−3.2.9 PARTIAL CHARGE. A partial charge is a charge that is insufficient to satisfy the requirements of paragraph 223−3.2.7 for a normal charge. A charge interrupted for some reason (for example, casualty or drills) and not restarted within one hour shall be considered a partial charge. It may be given to recharge a battery sufficiently to meet some special demand when time is lacking for a normal charge, or it may result from an interruption of normal charge caused by a breakdown or by reaching the temperature limits. Partial charging has advantages and disadvantages; however, the disadvantages as outlined in paragraph 223−3.2.9.2, outweigh any benefits.

223−3.2.9.1 Advantages of Partial Charges. With partial charges, the battery can be kept in a high state of charge with a minimum of time devoted to charg−

ing and the amount of overcharging is greatly reduced for the period in which partial charges are used. Therefore, less difficulty is encountered with high temperatures, and the amount of water used is reduced considerably.

223−3.2.9.2 Disadvantages of Partial Charges. The harmful effects of partial charges are reduced by the use of the electrolyte agitation system (paragraph 223−1.9.15). However, even with this device, partial charges should not be given routinely. Whenever operations permit, schedule normal and equalizing charges as required by paragraphs 223−3.3.1 and 223−3.3.2. The disadvantages of partial charging are not as easy to see from the operating viewpoint. Partial charging results in the electrolyte becoming highly stratified. The specific gravity may be above 1300 at the bottom of the plates and as low as 1000 at the top. This stratification produces several harmful effects described as follows:

a. Self−discharge. The high specific gravity at the lower end of the plates causes rapid self−discharge of the negative active material which reduces the end−of−charge voltage when an overcharge is given. The cell may deteriorate very rapidly with respect to chemical self−discharge. Hydrogen evolution on discharge and on open circuit may become several times as great, as compared with an operating procedure that eliminates partial charges.

b. Sulfation. Sulfation in the lower part of the plate is very difficult to reduce in all battery types because of the high specific gravity electrolyte in contact with these parts; as a result, the equalizing charges may have to be greatly prolonged to drive all the sulfate out of the plates after a period of successive partial charges.

c. Low Capacity. The low specific gravity acid at the top of the plate greatly reduces the capacity of the cell compared with a uniform electrolyte of the same average specific gravity. This may not be noticeable in routine operation in which less than 60 percent of the battery capacity is required. In more complete discharges, however, the effect will be evident.

223−3.2.10 CHARGE VOLTAGE CORRECTION FOR TEMPERATURE. To correct the voltage to 80°F when temperatures are taken in degrees Fahrenheit, add 0.003 volt per cell for the total number of cells in series for each degree Fahrenheit that the average pilot cell temperature exceeds 80°F, and subtract 0.003 volt per cell for the total number of cells in series for each degree Fahrenheit that the average pilot cell temperature is less then 80°F. The total corrected voltage (TCV) formula is:

$$\mathrm{TCV} = V_{swbd} + (0.003)(N)(Tc - 8)$$

Where: V_{swbd} = Switchboard voltage

N = Number of cells

T_c = Cell temperature

When temperatures are taken in degrees Celsius, correct to 26.7°C and use a correction factor of 0.005 volt in lieu of 0.003 volt. Charge voltage correction data is given in Table 223−11.

223−3.2.11 VOLTAGE LIMITS DURING CHARGE. The voltage limits of the TVG curve (paragraph 223−3.2.5) shall never be exceeded, except at the finishing rate, because the immediately resulting gassing can cause an explosive atmosphere in the battery well, especially at the higher rates. This can happen if the battery is not sufficiently discharged to take the starting rate or other rate selected to begin the charge, or if any rate is carried

Table 223−11. CHARGE VOLTAGE CORRECTION FOR TEMPERATURE

Voltage correction				Voltage correction			
Temperature				Temperature			
°F	°C	Single cell	126-Cell battery	°F	°C	Single cell	126-Cell battery
50	10.0	-0.090	-11.3	90	32.2	+0.030	+ 3.8
55	12.8	-0.075	- 9.5	95	35.0	+0.045	+ 5.7
60	15.6	-0.060	- 7.6	100	37.8	+0.060	+ 7.6
65	18.3	-0.045	- 5.7	105	40.6	+0.075	+ 9.5
70	21.1	-0.030	- 3.8	110	43.3	+0.090	+11.3
75	23.9	-0.015	- 1.9	115	46.1	+0.105	+13.2
80	26.7	-0.000	- 0.0	120	48.9	+0.120	+15.1
85	29.4	+0.015	+ 1.9	125	51.7	+0.135	+17.0
				130	54.4	+0.150	+18.9

beyond its proper limit. (see paragraph 223−3.2.6.1 for selection of initial charging rate)

223−3.2.12 TEMPERATURE LIMITATIONS DURING CHARGE. Average pilot cell electrolyte temperature should not exceed 130°F prior to completion of a charge. In order to comply with this requirement for convection cooled batteries, careful planning is required when scheduling discharge operations to insure that temperatures at the end of the discharge permit immediate and complete recharge. (See paragraph 223−3.5.10 for temperature limitations during discharge). Experience has shown that the rate of electrolyte temperature rise during charge/discharge operations increases significantly with increasing seawater temperature. Therefore, operating within temperature limits is more difficult when seawater temperature is above 70°F. With all other factors equal during a test discharge, the higher discharge rate for a GUPPY I MOD−E will result in a higher net temperature rise than a GUPPY I MOD−C. Ventilation inlet heaters should be secured if reaching temperature limits is a concern.

1. Starting temperature limit. A charge should not be initiated if the average pilot cell electrolyte temperature is greater than 100°F. However, during at sea operations the battery should never be left in a discharged condition while waiting for the battery to cool. Upon receiving permission from the Commanding Officer, a battery charge should be started with a planned interruption as described in 2 below.

2. Charge interruption. Recharge Ah initial limits are determined by the average pilot cell electrolyte temperature at the start of the charge. If the charge is not completed before reaching this Ah limit, the charge is interrupted, the rate of temperature rise is calculated, and the charge restarted until completed or until a final Ah limit is reached. Initial Ah limits are as follows. Charging with a starting temperature above 100°F requires permission from the Commanding Officer

STARTING TEMPERATURE (°F)	INITIAL Ah LIMIT	
	GUPPY I	TRIDENT
less than 90°F	none	none
90−100	4000	8000
100−110	3000	6000
110−115	2000	4000
115−120	1000	2000

Upon charge interruption, ventilate the battery compartment for at least 5 minutes followed by determination of average pilot cell electrolyte temperature. This and the starting temperature are used to calculate the rate of temperature rise per 1000 Ahs of charge for use in determining how many additional ampere−hours can be charged before reaching 125°F (5°F margin allowed for hot cells). This Ah value is the final Ah limit. Calculate the rate of temperature rise As follows. Make a note of seawater temperature.

$$R = \frac{T - Ts}{A}$$

Where: R = rate of temp rise per 1000 Ahs
T = temperature at time of interruption (°F)
Ts = starting temperature (°F)
A = Ahs recharged in units of 1000

Use R to determine the final Ah limit which is the point at which the electrolyte is predicted to reach 125°F. For example, if R = 5°F/1000 Ahs and T = 115°F, an additional 2000 Ahs of charge can be accomplished without exceeding 125°F. Restart the charge until completion or until the final Ah limit is reached. If the final limit is reached, place the battery on open circuit or trickle discharge until the average pilot cell electrolyte temperature has fallen sufficiently to permit completion of the charge as predicted by the value of R. If the seawater temperature has not changed more than ± 5°F, the value of R can be used for subsequent charges started at 90°F or higher. In such a case, the charge is not interrupted until this ampere−hour value is reached. For example, if seawater temperature has changed less than 5°F, and if R = 5°F/1000 Ahs, and if Ts is 95°F, the charge is not interrupted until it reaches 6000 Ahs at which point the electrolyte temperature is predicted to be at 125°F.

223−3.3 WHEN TO CHARGE

223−3.3.1 NORMAL CHARGES. Normal charges (paragraph 223−3.2.7) should be given:

a. At intervals not greater than seven days

b. When trickle and intermittent discharges exceed 1000 Ah for GUPPY I Mod C, 1400 Ah for GUPPY I Mod E and 2000 Ah for TRIDENT (see paragraph 223−3.5.14).

NOTE: USS DOLPHIN normal charges:

a. At intervals not greater than four days if battery has not been on open circuit

b. When specific gravity corrected for temperature drops to 1.150

c. When the battery has been on open circuit and is returned to service on or before the seventh day after the last charge.

223−3.3.2 EQUALIZING CHARGES. Equalizing charges (section 223−3.2.8, paragraph b) should be given:

a. At an interval not to exceed 30 + 3 days if not on open circuit

b. When specific gravity, corrected for temperature, drops to 1.175 for GUPPY I Mod C or TRIDENT, or 1.185 for GUPPY I Mod E

c. When discharges exceed 4000 Ah for GUPPY I Mod C, 5400 Ah for Mod E and 7500 Ah for TRIDENT without any kind of recharge

d. Between the sixth and seventh month of an open circuit period with less than 1000 Ah for GUPPY I Mod C, 1400 Ah for GUPPY I Mod E and 2000 Ah for TRIDENT of discharge (see 223−3.5.14).

NOTE: USS DOLPHIN equalizing charges:

a. At intervals not to exceed 28 days

b. When specific gravity corrected for temperature drops to 1.150.

223−3.3.3 FRESHENING CHARGES. Freshening charges (section 223−3.2.8, paragraph c) should be given:

a. Between the sixth and seventh month when the battery is in storage prior to installation onboard ship

b. A freshening charge is never given after battery installation onboard ship.

NOTE: USS DOLPHIN freshening charges:

a. With 40 days after the last charge completed before the battery was installed onboard ship

b. Every 21 days after first charge onboard ship when the battery is on open circuit and discharges have resulted in less than a 30 point drop in corrected specific gravity

c. When the battery has been on open circuit and returned to service between the seventh and twenty−first day after the last freshening charge.

223−3.3.4 PARTIAL CHARGES. Partial charges may be given as necessary (paragraph 223−3.2.9) provided normal and equalizing charges are given at the intervals specified in paragraphs 223−3.3.1 and 223−3.3.2.

223−3.3.5 CHARGING METHODS. Charging methods in general use are:

a. The constant potential method

b. The modified constant potential method.

223−3.3.5.1 Constant Potential Method. A storage battery may be charged within the shortest time without harm to the plates by the constant potential charge. In this method, the generator voltage is regulated to hold the battery voltage equal to the limit set by the TVG curve. The initial charging rate is equal to or less than the Ah previously discharged. The current decreases automatically as the battery approaches full charge. When the current decreases to the finishing rate, it is held constant until the charge is finished. Thus, the maximum charging rate permitted by the TVG curve is always maintained until the finishing rate is reached and the battery, therefore, becomes charged in the shortest possible time. The disadvantages of this method are that the in−

itial charging current may be beyond the capacity of the generators and cables and that very close regulation of the generator voltage is required.

223−3.3.5.2 Modified Constant Potential Method. The preferred charging method for all submarines is a modified constant potential charge. The charge is started with an initial charging current equal to the Ah previously discharged. If the initial current is below the capacity of the generators, the current is then increased to obtain a battery voltage equal to the voltage limit set by the TVG curve. If the initial current is at full generator capacity, it is held constant until the voltage limit is reached. In either case, when the cell voltage limit is reached, the battery voltage is held constant. The current decreases automatically as the battery approaches full charge. When the current decreases to the finishing rate, it is held constant until the charge is finished.

223−3.4 BATTERY CHARGING PERSONNEL RESPONSIBILITIES AND PROCEDURES

223−3.4.1 PERSONNEL RESPONSIBILITIES. The battery charging responsibilities and procedures in paragraphs 223−3.4.1 through 223−3.4.6 are based upon extensive experience with submarine storage battery operation, experimental data and lessons learned from battery explosions. Observe these instructions carefully to minimize explosion danger.

223−3.4.1.1 Supervisor. A battery charge of any nature, whether to charge the batteries or to load the engines while testing or warming up, shall be supervised by an officer who shall be onboard during the charge and who shall be responsible for seeing that all safety precautions are complied with. The officer shall be familiar with all equipment and the requirements of all orders, regulations and instructions pertaining to the conduct of a battery charge, including this volume.

223−3.4.1.2 Operators. A petty officer, examined and qualified by the submarine Commanding Officer to stand battery charging watches, shall man the control board for the charging generators, and at least one additional crew member, qualified by examination, shall assist the petty officer by taking battery readings and making prescribed inspections (paragraphs 223−3.1.6 and 223−3.1.7). The petty officer at the control board must remain on station at all times during the charge.

223−3.4.2 PREPARATION FOR ANY BATTERY CHARGE. Before starting a battery charge of any nature, take the following steps:

1. Take the specific gravity of all pilot cells; correct for temperature of electrolyte; and after correction, record as the corrected specific gravity at start of charge (paragraphs 223−3.1.6 and 223−3.1.7). Use average pilot cell temperature to determine TVG voltage (223−3.2.5).
2. Ensure that all service plugs are in place.
3. Inspect the entire battery exhaust system per Section 4.
4. Ensure that all battery exhaust fans and air supply ducts are operational, per Section 4.
5. Run battery exhaust fans throughout the charge and for a minimum of 20 minutes thereafter.
6. Ensure that the hydrogen detectors are turned on before starting a charge. Keep them in operation continuously throughout the charge. If readings were ab−

normal on the preceding charge, check detectors as prescribed by the instruction book. If tender or base facilities are available and calibration of meters is necessary, overhaul the meters before starting the charge.

7. Use the permanently installed ground−detector system to measure the resistance−to−ground from the battery and cables connecting it to the control cubicle. Except in an emergency, do not start the charge unless either the resistance−to−ground as measured on the permanently installed ground−detector system is more than 100,000 ohms. Clear the grounds, if necessary. See sections 223−6.6 and 223−6.7 for the procedure to be used in determining when these conditions are met, and section 223−6.7 for locating and clearing battery grounds. For emergency charging procedures, consult section 223−3.4.5 under conditions of low ground resistance.

8. The electrolyte agitation system (section 223−1.9.15 should be operating at all times for all battery types. If the system has been inactive for maintenance or other activity for a period greater than 24 hours, it should be operated for at least 24 hours prior to starting the charge. If proper air agitation is verified, the airflow meter (rotameter) value for this agitation rate should be recorded for reference during charge procedures (section 223−3.4.4.1).

223−3.4.2.1 Additional Preparations for an Equalizing Charge. Before starting an equalizing charge, take the following steps:

1. Take the specific gravity of all pilot cells; correct for temperature of electrolyte; and after correction, record as the corrected specific gravity at the start of the charge (paragraphs 223−3.1.6 and 223−3.1.7). Use average pilot cell temperatures to determine TVG voltage (paragraph 223−3.2.6).

2. If required and after taking pilot cell readings, add water from ship's demineralized (DI) water supply to restore the electrolyte in all cells to their normal level (paragraph 223−5.3.3.1). The need to add water occurs infrequently for lead−calcium batteries.

NOTE

DI water may be added at any convenient time provided the air agitation system is in operation. The preferred time to add water is prior to an equalizing charge (or normal charge, for USS DOLPHIN).

3. Note in the battery record book the amount of water used for watering each battery.

4. If a digital voltmeter has not been installed in the individual cell voltage (ICV) panel, conduct a 2−ohm load test (paragraph 223−6.3.1.5). If operations permit, conduct the test with battery on open circuit to detect high resistance (1.5 ohms) resulting from loose intercell connection.

5. If this charge is conducted during overhaul or extended restricted availability (RAV), satisfy the six to seven month equalizing charge requirement, inspect for loose cell connections, cracked jars and cell covers, disrupted ventilation ducts, loose or cracked flash arrester domes, loose wedges, dirt or acid in battery tanks, and cleanliness of cell tops and terminals. During periods of extended availability, for GUPPY I Mod C, add DI water to at least −10 points, −12 points for TRIDENT; with a tolerance of plus two points and minus zero points. This will prevent dry−out of cell separators from exposure.

6. Examine the ventilation system, inspect as recommended in Section 4.

7. For emergency charging procedures, consult paragraph 223−3.4.5 under conditions of low ground resistance.

223−3.4.2.2 Interruption of Charge. When a charge is interrupted for reasons other than ventilation problems and there has been no change in the ventilation lineup nor interruption of airflow, the charge may be resumed without repeating the preceding steps. If no discharge of the battery has taken place, the battery ampere−hour meter should not be reset, it will continue calculating charge from where it was suspended. If charge is suspended for ventilation problems these problems should be corrected per Section 4 instructions and the charging may resume when requirements of Section 4 are satisfied. Preparations specified in section 223−3.4.2.1 should be repeated.

223−3.4.3 CHARGING ORDER. A battery charging order containing complete instructions and safety precautions for conducting a battery charge shall be prepared for each submarine, and a copy shall be kept in a conspicuous place at the charging station. All personnel connected with charging shall become thoroughly familiar with its contents. The charging order shall include instructions that require routine inspections of the battery charging lineup and monitoring of battery airflow by the battery charging electrician to ensure integrity of battery ventilation lineup.

223−3.4.4 INSPECTIONS DURING CHARGE. Each time the charging current is recorded (as required in paragraph 223−3.4.6), check to see that the dampers are in the proper position and the fans are operating properly. Do not enter the battery well while a charge is in progress. Should it become necessary to enter the well to make an inspection, secure the charge before entering. Continue ventilating the battery compartment at the maximum ventilation rate possible with the installed battery compartment ventilation system. Ventilation shall continue, without interruption, for at least 20 minutes after securing the charge and before entering the well. While personnel are in the well, ventilation should be maintained as required for the battery condition. Resume full ventilation for at least 20 minutes before resuming the charge. See Section 9 for precautions to be taken while making inspections or working in the battery tank.

223−3.4.4.1 Agitation System Airflow. Read the airflow meter (Rotameter) in the electrolyte agitation system supply line at hourly intervals. Any large deviation from the normal air−flow rate for proper agitation as recorded in section 223−3.4.2, paragraph 8 should be investigated (paragraph 223−1.9.15).

223−3.4.5 GROUNDS DURING CHARGE. Use the appropriate ground resistant meters at 15−minute intervals during charge to check for grounds on the battery and the circuits and equipment connected to it (paragraphs 223−6.6 and 223−6.7). Except in an emergency, stop the charge if the resistance to ground falls below 100,000 ohms and make the additional tests necessary to determine whether the last condition stated in section 223−3.4.2, paragraph g is satisfied. If not, do not resume the charge until the ground or grounds have been located and cleared. See paragraphs 223−6.7.6 and 223−6.7.7 for the procedure to be followed in locating and clearing battery grounds.

223−3.4.5.1 Emergency Charging During Low Ground Resistance. During conditions of battery ground resistance lower than 100,000 ohms, the following procedure should be followed if an emergency charge is necessary.

WARNING

> Under no circumstances should a battery charge be attempted when the dc ground resistance is less than 50,000 ohms, since this may cause a point source of heat great enough to result in a fire.

Once the ground resistance is greater than 50K ohms the emergency charge may proceed. However, the charging rate shall not exceed a temperature−corrected total voltage equal to 2.33 volts per cell. The emergency charge is complete when the charging current reaches 50 amperes. Under conditions of ground resistance less than 100K ohms, equalizing charges are not permitted. At the next possible instance the grounds causing the low resistance should be cleared per paragraphs 223−6.6 through 223−6.7 and normal charging procedures resumed to restore battery levels to their normal operating condition.

223−3.4.6 READINGS TO BE RECORDED. The following records shall be kept for every battery charge:

a. The initial charging rate and the charging rate needed to obtain the TVG values are recorded. Except when the initial charging rate is increased to increase voltage to the TVG value, also record each charging rate and the time the rate was changed. With the modified constant potential charge, record the charging rate every 30 minutes until reaching the finishing rate and at 15−minute intervals thereafter.

b. Record the total battery voltage and the voltage of each pilot cell each time the charging current is recorded and just prior to completion of the charge.

c. Record the corrected specific gravity and temperature of all pilot cells:

1. Just prior to the charge. However, if the battery was watered just prior to the charge, record the corrected specific gravity existing just before watering.

2. Twenty minutes after completion of a normal charge as specified in the manufacturer's instructions.

3. During interruptions to and after completion of equalizing charges, as specified in the manufacturer's instructions, to verify cells have not exceeded specific gravity or temperature limits.

d. Record the Ah of charge each time the rate is recorded.

e. Record the airflow and the reading of the hydrogen detector each time the charging rate is recorded. However, keep these meters under constant observation while on the finishing rate above the TVG voltage.

f. Battery resistance ground readings should be made and recorded in the battery record book in accordance with section 223−6.7.

g. Enter on the rough log and in the battery record book any deviation from the prescribed routine and any unusual incidents or casualties to the entire system.

h. Just prior to completion of each equalizing charge, read and record in the rough log the total battery voltage and the voltage of all cells. The charge is not to be secured until all individual cell voltages have been recorded.

i. Complete reading and recording the specific gravity and height of electrolyte together and the temperature of each cell within four hours. However, if snorkel operation is to follow the charge, attempt to obtain the electrolyte height before snorkeling starts.

223−3.5 DISCHARGING

223−3.5.1 VENTILATION REQUIREMENTS DURING DISCHARGE AND ON STAND. Hydrogen is also evolved from lead acid batteries that are being discharged or that are on stand. Batteries being discharged or on open circuit must, therefore, be continuously ventilated. (see section 223−4.3.2.11)

223−3.5.2 CURVES AND DATA. A typical data plan is shown in Figure 223−2 and a typical battery characteristic curve, in Figure 223−3. Similar curves and data are furnished in the manufacturer's service manuals for each specified battery type. In addition to data on cell dimensions and weights, the curves and data plan furnish information on the battery discharge rates and capacities.

223−3.5.3 DISCHARGE RATES. Battery discharge rates are given on the data plan in Figure 223−2 and the ampere curves are shown in Figure 223−3. Battery discharge rates are commonly referred to as the half−hour rate, 1−hour rate, 10−hour rate, and so on. For example, the 1−hour rate for a certain battery is 5320 amperes and the 10−hour rate is 930 amperes. These mean that when a fully charged battery starts to discharge with an electrolyte temperature of 26.7°C (80°F), the battery is rated to deliver a constant current of 5320 amperes continuously for one hour before the voltage falls to a limiting voltage at which the discharge should be stopped; or 930 amperes continuously for 10 hours before the voltage falls to the limiting voltage for the 10−hour rate, which is different from that for the the 1−hour or any other rate (paragraph 223−3.5.4). The actual performance of a battery depends upon its age as well as other factors, but the hourly discharge rates are fixed values describing the battery service rating.

223−3.5.4 LOW VOLTAGE LIMITS ON DISCHARGE. In the table headed "Discharge Characteristics" of Figure 223−2, the data plan shows three low−voltage limits: the average final cell volts, the minimum final cell volts and the final voltage at the battery terminals. Except in an emergency, a battery discharge should be stopped when the average volts per cell falls to the average final cell volts; the total voltage of the battery falls to the final voltage at the battery terminals or the voltage of the lowest voltage cell falls to minimum final cell volts. Beyond this experimentally−determined voltage, little useful work will be obtained. All three voltage limits apply to cell or battery voltages measured on closed circuit with the battery discharging, and not corrected for temperature to 26.7°C (80°F). Therefore, if the limiting voltage at the battery terminals is 212 volts for a particular rate of discharge, a discharge at this rate is stopped when the measured voltage at the battery terminals falls to 212 volts, whatever the temperature of the battery may be.

223−3.5.4.1 Final Cell Voltage. The average final cell volts and minimum final cell volts are the voltages at the cell terminals. Since the individual cell voltmeter leads are normally connected to the negative terminals only, the individual cell voltmeter reading is equal to the voltage at the cell terminals minus the potential drop in the cell connectors between two adjacent cells. For all practical purposes, this difference is negligible and the individual voltmeter readings can be considered to give the voltage at the cell terminals.

223−3.5.4.2 Battery Voltage. The final voltage at the battery terminals is equal to the average final cell voltage times the number of cells in series minus the total voltage drop in all the cell connectors connected in series.

223−3.5.4.3 Voltage Limit vs. Discharge Rate. The limiting final voltages are different for different hourly discharge rates, being lower for discharges that last a short time than for those that last a long time. The limiting voltages are, however, independent of the specific gravity of the electrolyte when the battery is fully charged, the temperature of the electrolyte at the start of the discharge and the number of cycles the cell has been worked (paragraphs 223−3.5.8 and 223−3.5.9).

223−3.5.4.4 Exceeding Voltage Limits. Should an emergency necessitate continuing a discharge after the voltage of any cell has fallen to zero or reversed polarity, the cell should be used as a pilot cell during the next charge. If the cell overheats during the next charge, reduce the charging rate or cut the cell out as necessary. If the cell voltage or specific gravity is considerably lower than the battery average, see section 223−6.3.

223−3.5.5 CELL REVERSAL. During battery discharge, each cell approaches full discharge independently; therefore, one or more cells may reach the fully discharged condition before the battery voltage has reached the specified minimum value. Monitoring of the individual cell voltage at frequent intervals near the end of discharge will permit the condition to be detected and the discharge stopped. If the discharge is continued and a cell voltage is permitted to reach zero, the current flowing through the battery will continue to flow through the zero voltage cell and will charge the cell in the reverse direction. As the current continues to flow, a voltage will develop across the terminals of that cell, opposite the normal polarity voltage, causing abundant gas evolution (hydrogen and oxygen). A cell in that condition is said to have undergone cell reversal. (see paragraph 223−3.5.5 for addition information)

223−3.5.6 DURATION OF DISCHARGE. The length of time that a battery will maintain a discharge at any given hourly rate depends upon the age of the battery, the rate of discharge and the temperature of the electrolyte at the start of discharge. At first, the capacity of a new battery usually increases with the number of cycles it is worked. The service rating given on the curves and data plan specifies the level of performance the battery is guaranteed to develop by the time it has been worked 30 equivalent cycles. The service rating for the duration of discharge under different conditions is shown on the curves and data plan (Figure 223−2) in the table under ”Discharge Characteristic.” Reference to the discharge characteristics shows that when the initial temperature of the electrolyte is 26.7°C (80°F), the rated duration of discharge at each hourly discharge rate is equal to the number of hours specified as the discharge rate in the far left column of the table. If the initial temperature of the electrolyte is below 26.7°C (80°F), the rated time of discharge is less than the number of hours specified as the discharge rate; if the initial temperature is above 26.7°C (80°F), the rated time of discharge is more than the number of hours specified as the discharge rate. For a battery that has been worked fewer than the minimum number of cycles, the rated duration of discharge is found in paragraph 223−3.5.8.

223−3.5.7 AMPERE−HOUR CAPACITY DEFINED. The number of Ah delivered by a battery on discharge is equal to the time of discharge, in hours, times the average discharge current, in amperes. The capacity of a battery is the number of Ah it is capable of delivering on discharge before the discharge must be terminated because a low−voltage limit has been reached.

223−3.5.7.1 Factors in Determining Capacity. Ampere−hour capacity depends upon a number of factors in addition to the type of battery and its construction. Among these are: the age of the battery (223−3.5.9), the specific gravity of the electrolyte when the battery is charged (paragraph 223−3.1.8), the rate of discharge (paragraph 223−3.5.3), the temperature of the electrolyte at the start of a discharge (paragraph 223−3.5.10) and recent nonuse (paragraph 223−3.5.7.5).

223−3.5.7.2 Effect of Specific Gravity on Capacity. The hourly discharge rates and, consequently, the capacities at the different rates are higher at a higher specific gravity than at a lower specific gravity in the fully charged condition. Any increase in capacity obtained by increasing specific gravity is gained at the expense of decreased battery life and of increased operating difficulties. The specific gravity used in any specific type of battery is a compromise expected to give the most satisfactory results when all factors are considered.

223−3.5.7.3 Current, Hourly Rates and Capacity. Other conditions being the same, the capacity decreases as the discharge current increases. This is illustrated by the data shown in Figure 223−2. When the specific gravity is 1.285 in the fully charged condition and a discharge is started at an initial electrolyte temperature of 26.7°C (80°F), each cell is rated to deliver 4000 amperes for one hour before reaching the low−voltage limits for this rate, 1.46 volts; or 680 amperes for 10 hours before reaching 1.69 volts, the low−voltage limit at the 10−hour rate. The rated Ah capacity at the 1−hour rate, therefore, is 4000 Ah; at the 10−hour rate, 6800 Ah. The approximate percentage of the 3−hour capacity obtainable at other hourly rates is shown in Table 223−12.

223−3.5.7.4 Effect of Temperature on Capacity. At any discharge current, the rated time of discharge increases with the temperature. The capacity, therefore, increases proportionately.

223−3.5.7.5 Effect of Recent Nonuse on Capacity. If a battery is unused for 30 days or more it will show a drop in capacity at all discharge rates, depending on length of nonuse. This is especially true of new batteries with few equivalent cycles. Ampere−hour capacity will return to normal after the battery is returned to service and accumulates at least two to eight equivalent cycles.

223−3.5.8 SERVICE RATING FOR BATTERIES. The battery rating shown on the curves and data plan is the service rating. Batteries are guaranteed to develop the service rating after 30 equivalent cycles. (see paragraph 223−3.1.11 for a definition of equivalent cycles) A battery that has been worked less than the specified number of equivalent cycles is not expected to have full−service capacity. The hourly rates of discharge and the low−voltage limits are the same as for a battery that has full−service capacity. The duration of discharge at any specified rate however, is less, and is found by referring to the curves and data plan for the battery and finding the service rating for the duration of discharge for the discharge rate used and the electrolyte temperature at the beginning of the discharge.

223−3.5.9 VARIATION OF CAPACITY WITH AGE AND WORKING. The capacity of a storage battery, even one fully charged prior to each test, varies appreciably during its life. In general, the capacity builds up after the initial charge (paragraph 223−3.5.8), reaches a maximum early in life, and then declines slowly until it drops below 90 percent of

Table 223−12. RATE OF DISCHARGE VS AH CAPACITY

(TLX-39B)* Rate of discharge	Ampere-hour (Ah) capacity (Percent of capacity at 3-hour rate)
1	76
3	100
6	117
10	130
20	141

* GUPPY I Mod C (LC) battery

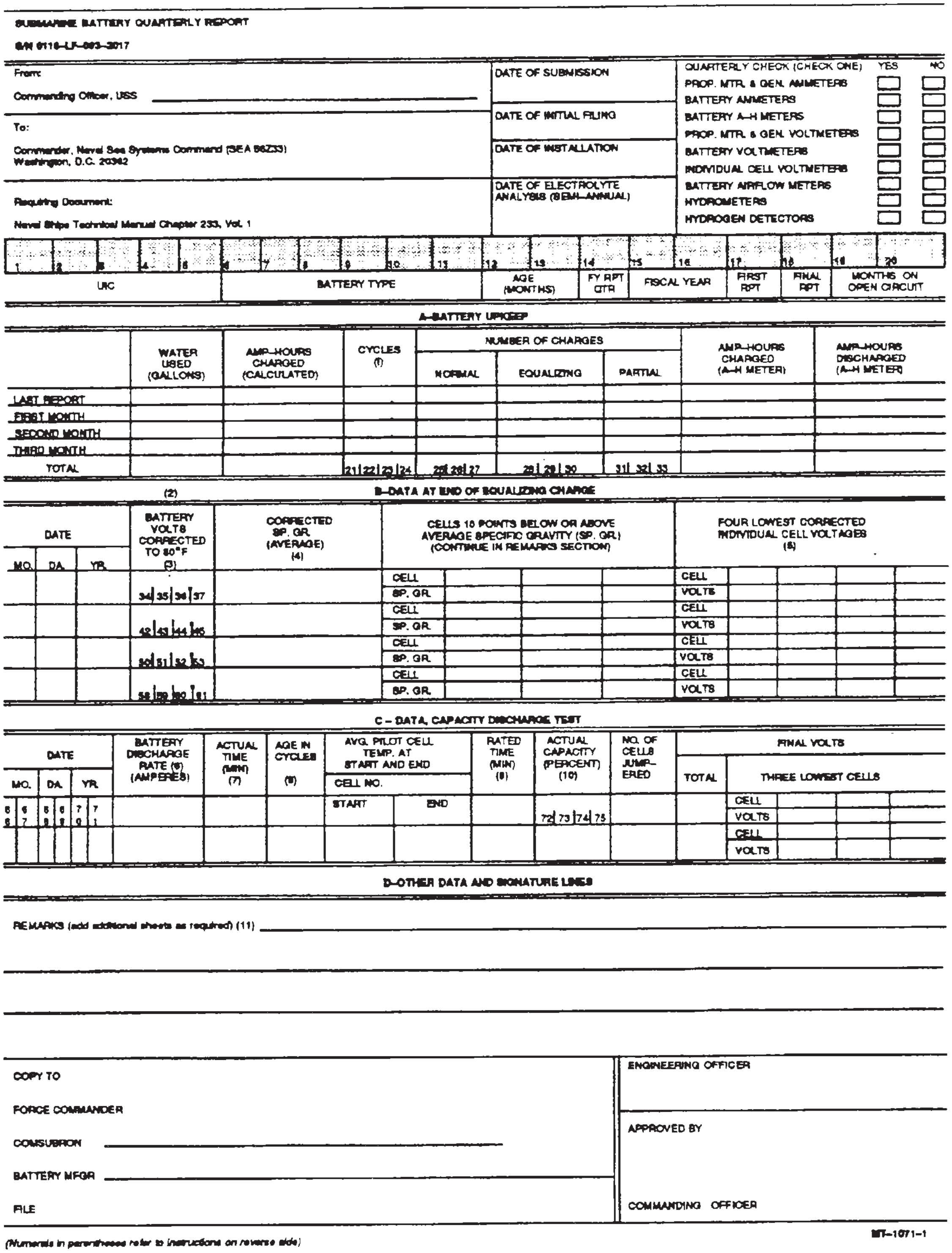
rated capacity. Batteries are not guaranteed to deliver rated capacity until a specified minimum working number of equivalent cycles have been given (paragraph 223−3.5.8). Tests made during the battery life to determine the battery capacity should follow the guidelines of paragraph 223−5.5.4. The results should be reported on the Submarine Battery Quarterly Report, NAVSEA form 9320/3, (Figure 223−16).

223−3.5.10 TEMPERATURE LIMITATION ON DISCHARGE. Operation at temperatures above 54°C (130°F) should be considered an emergency measure and held to an absolute minimum. Repeated operation at higher temperatures may result in nullification of battery guarantees, reduction in battery life, and excessive hydrogen evolution during submergence. Problems are detailed in paragraph 223−1.5.3.5. In addition, battery sealing compound may flow into the cells with loss of sealing and impairment of cell ventilation. To operate batteries without exceeding this temperature requires careful planning during trials and other tests under warm operating conditions. Long cooling intervals and interrupted equalizing charges are usually necessary.

223−3.5.10.1 Temperature Rise. Temperature rise on a complete discharge will be 2−3°F for a 6−hour rate, 10−20°F for a 3−hour rate, and 25−35°F for a 1−hour rate depending on starting temperature, seawater temperature and battery type. If the starting temperature is considerably above the ambient, the battery will cool on discharge at the 6−hour or longer rate.

223−3.5.10.2 Test Discharge Starting Temperature. A test discharge should be carefully planned to allow an average pilot cell electrolyte end temperature which allows immediate and complete recharge without need for interruption (see paragraph 223−3.2.12). To do this, the electrolyte starting temperature for the test should be 70−80°F. When the starting temperature for a test discharge is greater than 80°F, recharge temperature restrictions (paragraph 223−3.2.12) are likely. If the average pilot cell electrolyte temperature is greater than 100°F after completing the equalizing charge prior to a test discharge, place the battery on open circuit or on trickle discharge. If the battery does not cool to below 90°F within 36 hours the test should be postponed and rescheduled for just after completion of the next normal charge. The Quarterly Battery Report should make note that this test was preceded by a normal charge due to temperature restrictions.

223−3.5.10.3 Operating Despite High Temperatures. Engineering trials and vital operations should not be interrupted in order to hold the battery temperatures below 54°C (130°F). However, if submerged operation at temperatures in excess of 54°C (130°F) becomes necessary, account should be taken of the high rate of



SUBMARINE BATTERY QUARTERLY REPORT

S/N 0116-LF-093-2017

From: Commanding Officer, USS ______	DATE OF SUBMISSION	QUARTERLY CHECK (CHECK ONE) YES NO PROP. MTR. & GEN. AMMETERS ☐ ☐ BATTERY AMMETERS ☐ ☐ BATTERY A–H METERS ☐ ☐ PROP. MTR. & GEN. VOLTMETERS ☐ ☐ BATTERY VOLTMETERS ☐ ☐ INDIVIDUAL CELL VOLTMETERS ☐ ☐ BATTERY AIRFLOW METERS ☐ ☐ HYDROMETERS ☐ ☐ HYDROGEN DETECTORS ☐ ☐
To: Commander, Naval Sea Systems Command (SEA 56Z33) Washington, D.C. 20362	DATE OF INITIAL FILING DATE OF INSTALLATION	
Requiring Document: Naval Ships Technical Manual Chapter 233, Vol. 1	DATE OF ELECTROLYTE ANALYSIS (SEMI–ANNUAL)	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
UIC					BATTERY TYPE						AGE (MONTHS)		FY RPT QTR	FISCAL YEAR		FIRST RPT	FINAL RPT	MONTHS ON OPEN CIRCUIT	

A–BATTERY UPKEEP

	WATER USED (GALLONS)	AMP–HOURS CHARGED (CALCULATED)	CYCLES (1)	NUMBER OF CHARGES			AMP–HOURS CHARGED (A–H METER)	AMP–HOURS DISCHARGED (A–H METER)
				NORMAL	EQUALIZING	PARTIAL		
LAST REPORT								
FIRST MONTH								
SECOND MONTH								
THIRD MONTH								
TOTAL			21 22 23 24	25 26 27	28 29 30	31 32 33		

(2) B–DATA AT END OF EQUALIZING CHARGE

DATE			BATTERY VOLTS CORRECTED TO 80°F (3)	CORRECTED SP. GR. (AVERAGE) (4)	CELLS 10 POINTS BELOW OR ABOVE AVERAGE SPECIFIC GRAVITY (SP. GR.) (CONTINUE IN REMARKS SECTION)				FOUR LOWEST CORRECTED INDIVIDUAL CELL VOLTAGES (5)				
MO.	DA.	YR.											
			34 35 36 37		CELL SP. GR.				CELL VOLTS				
			42 43 44 45		CELL SP. GR.				CELL VOLTS				
			50 51 52 53		CELL SP. GR.				CELL VOLTS				
			58 59 60 61		CELL SP. GR.				CELL VOLTS				

C – DATA, CAPACITY DISCHARGE TEST

DATE			BATTERY DISCHARGE RATE (6) (AMPERES)	ACTUAL TIME (MIN) (7)	AGE IN CYCLES (8)	AVG. PILOT CELL TEMP. AT START AND END		RATED TIME (MIN) (9)	ACTUAL CAPACITY (PERCENT) (10)	NO. OF CELLS JUMPERED	FINAL VOLTS			
MO.	DA.	YR.				CELL NO.					TOTAL	THREE LOWEST CELLS		
66 67	68 69	70 71				START	END		72 73 74 75			CELL VOLTS		
												CELL VOLTS		

D–OTHER DATA AND SIGNATURE LINES

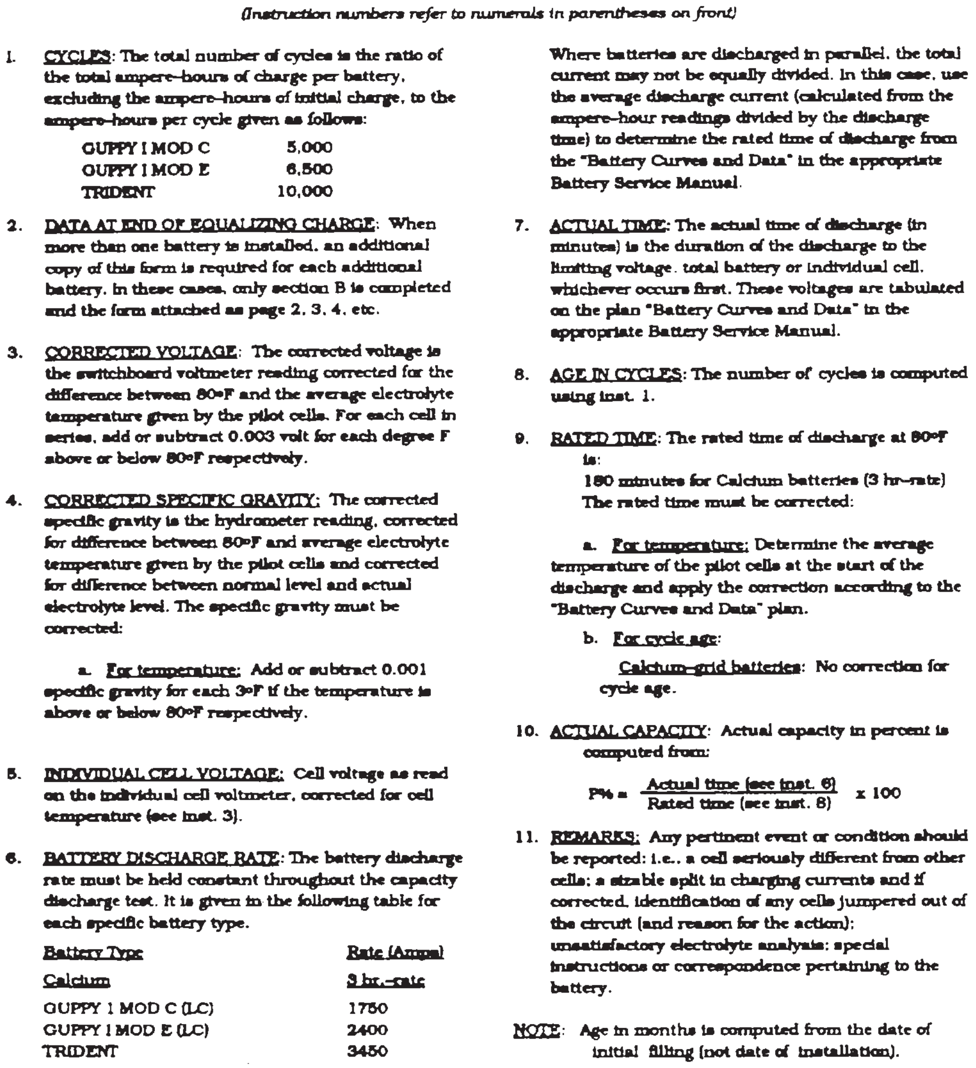
REMARKS (add additional sheets as required) (11) ______

COPY TO FORCE COMMANDER COMSUBRON ______ BATTERY MFGR ______ FILE	ENGINEERING OFFICER APPROVED BY COMMANDING OFFICER

(Numerals in parentheses refer to instructions on reverse side)

MT–1071–1

Figure 223−16. Submarine Battery Quarterly Report (Sheet 1 of 2)



(Instruction numbers refer to numerals in parentheses on front)

1. CYCLES: The total number of cycles is the ratio of the total ampere–hours of charge per battery, excluding the ampere–hours of initial charge, to the ampere–hours per cycle given as follows:

GUPPY I MOD C	5,000
GUPPY I MOD E	6,500
TRIDENT	10,000

2. DATA AT END OF EQUALIZING CHARGE: When more than one battery is installed, an additional copy of this form is required for each additional battery. In these cases, only section B is completed and the form attached as page 2, 3, 4, etc.

3. CORRECTED VOLTAGE: The corrected voltage is the switchboard voltmeter reading corrected for the difference between 80°F and the average electrolyte temperature given by the pilot cells. For each cell in series, add or subtract 0.003 volt for each degree F above or below 80°F respectively.

4. CORRECTED SPECIFIC GRAVITY: The corrected specific gravity is the hydrometer reading, corrected for difference between 80°F and average electrolyte temperature given by the pilot cells and corrected for difference between normal level and actual electrolyte level. The specific gravity must be corrected:

   a. For temperature: Add or subtract 0.001 specific gravity for each 3°F if the temperature is above or below 80°F respectively.

5. INDIVIDUAL CELL VOLTAGE: Cell voltage as read on the individual cell voltmeter, corrected for cell temperature (see inst. 3).

6. BATTERY DISCHARGE RATE: The battery discharge rate must be held constant throughout the capacity discharge test. It is given in the following table for each specific battery type.

Battery Type	Rate (Amps)
Calcium	3 hr.-rate
GUPPY I MOD C (LC)	1750
GUPPY I MOD E (LC)	2400
TRIDENT	3450

Where batteries are discharged in parallel, the total current may not be equally divided. In this case, use the average discharge current (calculated from the ampere–hour readings divided by the discharge time) to determine the rated time of discharge from the "Battery Curves and Data" in the appropriate Battery Service Manual.

7. ACTUAL TIME: The actual time of discharge (in minutes) is the duration of the discharge to the limiting voltage, total battery or individual cell, whichever occurs first. These voltages are tabulated on the plan "Battery Curves and Data" in the appropriate Battery Service Manual.

8. AGE IN CYCLES: The number of cycles is computed using inst. 1.

9. RATED TIME: The rated time of discharge at 80°F is:

   180 minutes for Calcium batteries (3 hr–rate)
   The rated time must be corrected:

   a. For temperature: Determine the average temperature of the pilot cells at the start of the discharge and apply the correction according to the "Battery Curves and Data" plan.

   b. For cycle age:

      Calcium–grid batteries: No correction for cycle age.

10. ACTUAL CAPACITY: Actual capacity in percent is computed from:

$$P\% = \frac{\text{Actual time (see inst. 6)}}{\text{Rated time (see inst. 8)}} \times 100$$

11. REMARKS: Any pertinent event or condition should be reported: i.e., a cell seriously different from other cells; a sizable split in charging currents and if corrected, identification of any cells jumpered out of the circuit (and reason for the action); unsatisfactory electrolyte analysis; special instructions or correspondence pertaining to the battery.

NOTE: Age in months is computed from the date of initial filling (not date of installation).

Figure 223−16. Submarine Battery Quarterly Report (Sheet 2 of 2) hydrogen evolution at these temperatures (paragraph 223−1.5.3.5).

223−3.5.10.4 Emergency Operations Under High Temperature. For emergency operation, the limiting cell temperature, beyond which irreparable damage may be done, should be taken as 68°C (155°F). If only the two pilot cells in the battery are used as guides, 66°C (150°F) should be taken as the limiting temperature as a precaution against any cell exceeding 68°C (155°F). It should be noted that during a 1−hour rate discharge, the high battery cable temperature may cause the terminal cells, which are usually cool, to become the hottest cells.

223−3.5.11 READINGS DURING DISCHARGE. Readings of the battery total voltage and the specific gravity and temperature of the pilot cells during discharge shall be taken and recorded in accordance with the requirements of the engineering log (electrical), the battery record book, and the forms provided for special discharges. When the limiting final cell or total voltage is being approached, individual cell and total battery voltages shall be read as frequently as necessary to avoid discharging beyond the prescribed limits (paragraph 223−3.5.4).

223−3.5.12 OBTAINING ADDITIONAL CAPACITY. More capacity than can be obtained on continuous discharge at any constant rate in amperes can be obtained by repeated interruptions in the discharge, or by gradually lowering the current during the discharge to allow time for the electrolyte to diffuse through the active material. The trickle discharge mode for lead−calcium batteries provides for the most efficient and extended capacity of the battery grids (see section 223−3.5.14). For example, if the battery is discharged at the 1−hour or the 3−hour rate and the discharge is interrupted at regular and frequent intervals to make it extend over a period of eight hours, a capacity approximating the 8−hour rate capacity may be obtained. Similarly, if a battery is initially discharged at the 1−hour rate and the current is progressively reduced to the 10−hour rate, always keeping above the low−voltage limit for the rate momentarily used, a capacity approximately equal to the 10−hour capacity will be obtained. In either case, any further capacity which might be gained by discharging below the low−voltage limit would be very small. Therefore, the discharge must be stopped or the rate reduced when the voltage drops to the low−voltage limit for the rate of discharge being used (paragraph 223−3.5.4).

223−3.5.13 CALCULATION OF AH OUTPUT AND RESIDUAL CAPACITY. The number of Ah that have been discharged by a storage battery cell can be: determined by reading the Ah meter (paragraph 223−3.5.13.1); calculated from the discharge current and the time it flows (paragraph 223−3.5.13.2); estimated from the drop in specific gravity that occurred during the discharge (paragraph 223−3.5.13.3); or, estimated from the number of volts above the low−voltage limit (paragraph 223−3.5.13.4). The residual capacity in Ah at a given rate can be: calculated by the efficiency method (paragraph 223−3.5.13.7); or, estimated from the voltage under load at that given rate (paragraph 223−3.5.13.13).

223−3.5.13.1 Calculation of Ah Output from Ah Meter. Ampere−hour meters can be used to determine the Ah of discharge during routine operations. However when a test discharge is to be run on a battery, the method described in paragraph 223−3.5.13.2 shall be used.

223−3.5.13.2 Calculation of Ah Output from Current and Time. Given the accuracy of the presently installed ampere−hour meters calculation of the Ah output from current and time is the only accurate and reliable method for determining the actual capacity output. However, this method does not give the residual capacity at any discharge rate (paragraphs 223−3.5.13.4 through 223−3.5.13.13). The Ah discharged when the current is constant is found by multiplying the current in amperes by the time of discharge in hours. When the current varies, the total time of discharge is broken up into short intervals so that the current is constant in each interval, though different from one interval to another. Each time interval is multiplied by its current. The sum of the products gives the total number of Ah discharged. Thus, if a battery has supplied 200 amperes for one hour, 2000 for 1/4 hour, 300 for three hours, and 1000 for 1/2 hour, the equation for calculating the total number Ah discharged is:

$$200 \text{ x } 1 + 2{,}000 \text{ x } 1/4 + 300 \text{ x } 3$$

$$+ 1{,}000 \text{ x } 1/2 = 2{,}100 \text{ Ah.}$$

223−3.5.13.3 Calculation of Ah Output from Specific Gravity Drop. The drop in specific gravity, corrected for temperature of electrolyte, is theoretically directly proportional to the number of Ah discharged and is independent of the discharge rate and battery temperature (paragraph 223−1.5.5.) Consequently, the number of Ah discharged can be estimated for any battery by multiplying the number of points (0.001) of drop in corrected specific gravity by the Ah per point, (paragraph 223−3.1.8).

NOTE

When using this method to calculate the number of Ah discharged, always bear in mind that the drop in specific gravity does not exactly represent the Ah discharged unless the electrolyte above the plates has had an opportunity to mix with the less concentrated electrolyte between the plates.

The apparent drop in specific gravity, as determined by measuring the electrolyte above the plates, is always less than the actual drop. This error is small when the average discharge current is less than or equal to the current corresponding to the 20 hour discharge rate, and only about five percent for a discharge at the 10−hour rate. It becomes increasingly larger for discharges at higher current, and the apparent drop in specific gravity, as determined by measuring the specific gravity of the electrolyte above the plates at the end of a discharge at the 1−hour rate, may be only about half the actual drop for the whole body of electrolyte. This method is never accurate and should not be used for determining and reporting Ah capacity output.

223−3.5.13.4 Estimate of Residual Capacity From Voltage Under Load. Voltage under load furnishes a conclusive indication of a state of complete discharge since the low−voltage limit is the criterion determining when a discharge shall be stopped. But for a battery that is only partly discharged, the voltage is a far less certain guide to the state of discharge. The general relationship between the discharge rate, the amount of discharge, and the voltage is simply that the greater the discharge rate in amperes and the more the battery is discharged, the lower the voltage will be. This relationship is greatly affected by other factors such as the age of the battery, the previous cycling, the actual battery capacity and the temperature. This method is, therefore, suitable for estimating residual capacity, but is unsuitable for accurately determining the state of charge, particularly for a battery less than 50 percent discharged.

223−3.5.13.5 Rate of Voltage Drop. In Figure 223−17, the voltage is shown plotted against Ah output for discharges at constant rates in amperes. The rate of voltage decrease is small from the start until the battery is approximately 50 percent discharged. After this, the voltage drops faster until the limiting voltage is reached. The curves representing various discharge rates show the voltage characteristics (126 cells) at 26.7°C (80°F).

223−3.5.13.6 Use of Data. In view of the large change in the state of discharge corresponding to a small change in the total voltage when the battery is less than 50 percent discharged, it is apparent that the state of discharge versus voltage above low−voltage limit data shown in Table 223−13 must be used with caution. Particular care should be taken to determine the rate of voltage drop. The voltage drop is more indicative of the state of discharge than is the actual voltage; for example, the change in voltage from 80 percent to 90 percent discharged is between two and three times as great as is the change in voltage from 30 percent to 40 percent discharged.

223−3.5.13.7 Calculation of Residual Capacity by Efficiency Method. Assuming an efficiency value factor of 1.00 for the 10−hour rate output, any higher rate, such as the 1−, 3−, or 4−hour rates, yields a lower output than the 10−hour rate. The following lists empirical values of the efficiency factor as established for a battery giving 100 percent capacity on a test discharge at 680 amperes at 26.7°C (80°F)

Current (A)	Efficiency factor
680	1.00
1025	0.90
1750	0.75
2000	0.72
2500	0.66
3000	0.60
3500	0.54
4000	0.50
4500	0.48
5000	0.46

From a curve plotting the above efficiency factors versus current, any intermediate value could be immediately interpolated.

223−3.5.13.8 Obtaining Capacity at the 10−Hour Rate. After a test discharge at the 3−hour rate on a TLX−39B battery, the Ah capacity at the 10−hour rate can be calculated using the percentage value, 130 percent, given in Table 223−12. The calculated value will be within five percent of the actual value depending on battery age, length of time since last test discharge, and absence of any malfunction, such as a sulfated or shorted cell that would have lowered capacity since the test discharge.

223−3.5.13.9 Obtaining Partial Output Values. After a battery has been partially discharged at a single rate or at any combination of rates, the length of time that a discharge can be expected to continue at a new desired rate (assuming that all temperatures are normalized to 26.7°C

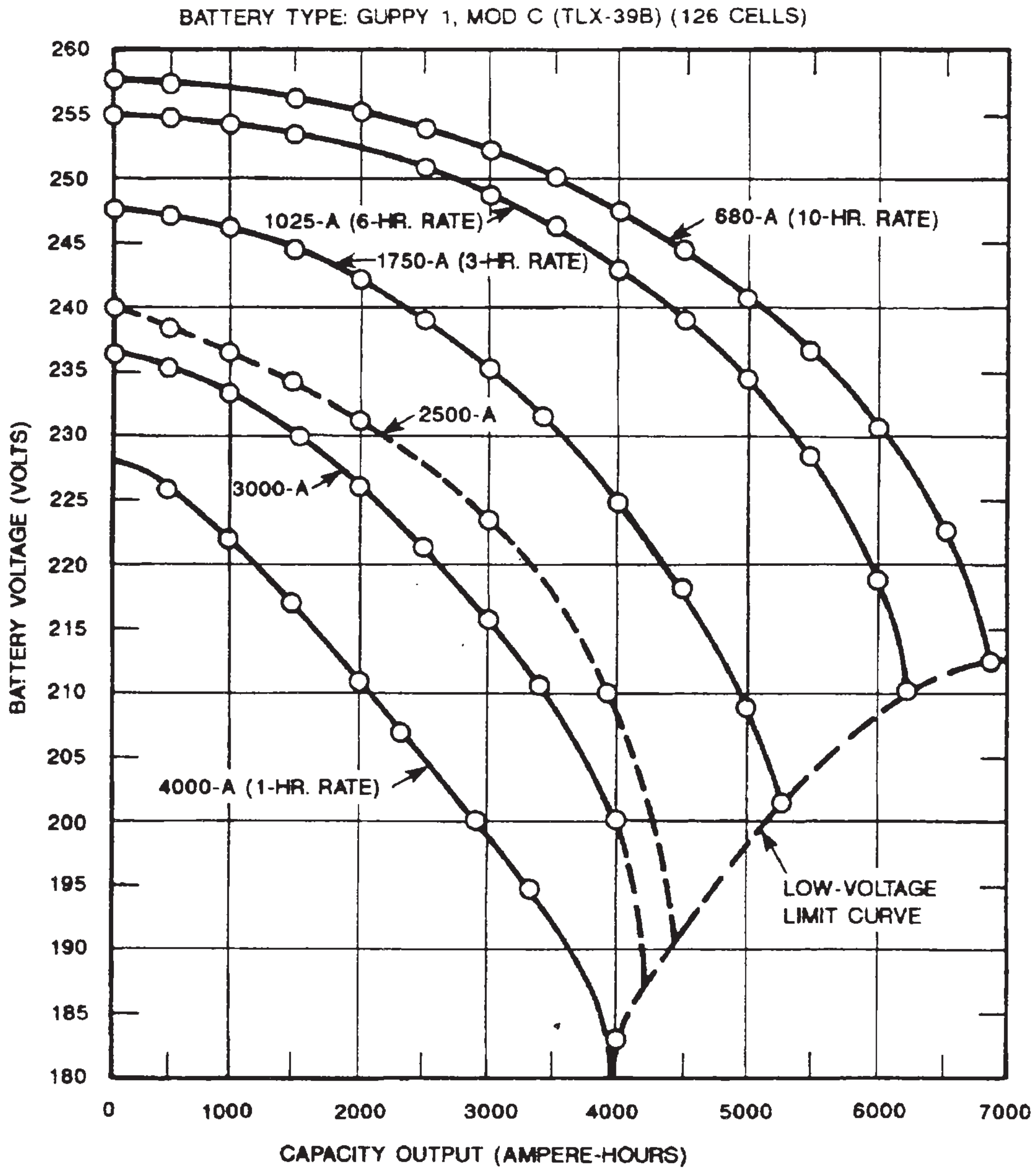


Figure 223−17. Typical Discharge Curves at 26.7°C (80°F)

Table 223−13. STATE OF DISCHARGE VS. VOLTS ABOVE LOW VOLTAGE LIMIT (FOR A TLX-39B BATTERY)

Percent discharged	Volts above the low voltage limit at the indicated ampere-hour (Ah) rate			
	4000 A (1-Hr)	1750 A (3-Hr)	1025 A (6-Hr)	680 A (10-Hr)
0	48	47	46	46
10	46	45	45	45
20	43	43	44	44
30	39	41	43	42
40	36	39	40	40
50	33	36	37	37
60	28	33	34	34
70	25	28	30	31
80	20	25	27	27
90	13	18	20	22
100	0	0	0	0

(80°F)) is found by first determining the Ah output (number of Ah taken out of the battery), for each partial discharge. The Ah output is found from the reading of the Ah meter (paragraph 223−3.5.13.1) or from the current and time duration of the partial discharge (paragraph 223−3.5.13.2).

223−3.5.13.10 Residual Capacity at the 10−Hour Rate. To calculate the residual capacity at the 10−hour rate for each partial discharge, divide the Ah output by the efficiency factor corresponding to the current of the partial discharge (paragraph 223−3.5.13.12, example a), and add all the outputs so corrected (paragraph 223−3.5.13.12, example b). Subtract this total from the Ah output at the 10−hour rate as calculated in paragraph 223−3.5.13.8 (paragraph 223−3.5.13.12, example c).

223−3.5.13.11 Residual Capacity at Other Rates. To find the residual capacity at other rates, multiply the result obtained in paragraph 223−3.5.13.10 for the 10−hour rate by the efficiency factor corresponding to the alternate rate (paragraph 223−3.5.13.12, example d). If the residual time is desired, divide the above figure by the desired rate (paragraph 223−3.5.13.12, example e).

223−3.5.13.12 Example of Residual Capacity at Other Rates. Assume a TLX−39B battery. At the 3−hour rate, this battery had an output of 5000 Ah during the last test discharge. Since it was last fully charged, the battery has supplied 2000 amperes for one half−hour (1000 Ah), then 1025 amperes for one hour (1025 Ah). How much residual capacity or time is left at the 1−hour rate (4000 amperes)?

Solution:

Calculate capacity at the 10−hour rate using the last test discharge and Table 223−12 data:

[3−hour rate capacity] x

[percentage for 10−hour rate capacity]

5000 Ah x 1.30 = 6500 Ah

The efficiency factors given in paragraph 223−3.5.13.7 at 2000 amperes, 1025 amperes and 4000 amperes, respectively, are 0.72, 0.90 and 0.50.

a. Correcting each partial discharge to the 10−hour rate:

$$\frac{1000\ \text{Ah}}{0.72} = 1380\ \text{Ah}$$

$$\frac{1025\ \text{Ah}}{0.902} = 1140\ \text{Ah}$$

b. The total output corrected to the 10−hour rate would be:

1380 Ah + 1140 Ah = 2520 Ah

c. The residual capacity at the 10−hour rate is:

6500 Ah − 2520 Ah = 3980 Ah

d. The residual capacity at the 1−hour rate (4000 amperes) would be:

3980 Ah x 0.50 = 1990 Ah

e. The residual time at the 1−hour rate is:

$$\frac{1990}{4000} = 0.50 \text{ hour or approximately 30 minutes.}$$

NOTE

All above calculations are rounded off as they give only estimates valid within 10 to 15 percent.

223−3.5.13.13 Calculation of Residual Capacity by Estimate of Voltage Under Load. The residual capacity at a given rate can be calculated by estimating the voltage under load.

a. Read the initial battery voltage immediately after applying the load at that particular given rate.

b. Knowing the total capacity output (223−3.5.13.2), Q_T, to the low−voltage limit at that particular rate, plot the voltage reading on the curve of Figure 223−17 corresponding to the given rate to get the potential capacity output, Q_o, that would have been taken out if that rate had been applied from the fully charged state.

c. The difference, $Q_T - Q_o$, gives the residual capacity, Q_R, at that particular rate.

d. For any rate and voltage not falling on curves shown in Figure 223−17, interpolation is required. Linear (proportional) interpolation is sufficient as the estimates are valid only within 10 to 15 percent.

Assume that the TLX−39B battery has been partially discharged at various rates.

a. Applying a load of 3500 amperes, the initial voltage obtained is 208 V.

b. Since 3500 amperes is not shown on the Figure 223−17, a midpoint between 4000 amperes and 3000 amperes curves on the horizontal of 208 V gives a reading for Q_o of 3000 Ah on the capacity output scale.

c. The total output at 3500 amperes is estimated to be 4200 Ah (Q_T) to the low−voltage limit.

d. Therefore, the residual capacity is 4200 − 3000 = 1200 Ah (Q_R).

223−3.5.14 TRICKLE−DISCHARGE FOR LEAD−CALCIUM BATTERIES. Lead−calcium grid batteries are not to be floated because their capacity declines if they are floated for long periods (section 223−3.2.8, paragraph e). The so−called trickle−discharge routine has proven to be beneficial to the capacity maintenance of these batteries. The discharge rate has been fixed low enough (four to seven amperes, with an average of five amperes for GUPPY I Mod C; five to 10 amperes, with an average of seven amperes for GUPPY I Mod E; and seven to 14 amperes, with an average of 10 amperes for TRIDENT) to avoid unnecessary usage cycles. The trickle−discharge rate is to be maintained until the battery is discharged: approximately 1000 Ah for GUPPY I Mod C, 1400 Ah for GUPPY I Mod E and 2000 Ah for TRIDENT or for seven days, whichever occurs first, after which the battery must be recharged. This routine does not apply if the battery is needed for other loads, in which case the 1000 Ah for GUPPY I Mod C, 1400 Ah for GUPPY I Mod E and 2000 Ah for TRIDENT requirement may be exceeded if an equalizing charge is scheduled, or if, at any time during this trickle−discharge routine, there is need to recharge the battery in order to have a fully charged battery for operating needs. Further information may be found in the manufacturer's service manuals.

223−3.5.14.1 Maintaining Discharge Rate. Fluctuations in battery discharge rates will occur when load changes on the ship's direct current (dc) bus are more rapid than the response characteristics of the Ship's Service Motor Generator (SS M/G) voltage regulators. These load fluctuations cause oscillation of the battery float ammeter. Trickle−discharge rate for TLX−39B is between four and seven amperes (five ampere average), ASB−49 is between five and nine amperes (seven ampere average) and SCC−57/PDX−57 is between seven and 14 amperes (10 ampere average). In maintaining the trickle−discharge rate, manual control of SS M/G regulated voltage to overcome expected battery float ammeter oscillation is not required when the oscillations are centered on the average discharge rate. It is recognized that the battery float ammeter will occasionally indicate charge instead of discharge. However, the average discharge rate is intended and can be maintained. It is also recognized that, as more oscillations into the charge side of the battery float ammeter occur, the Ah meter readings will be increasingly inaccurate since the Ah meter does not differentiate between charge or discharge. As a result, the ratio of Ah charged to Ah discharged is also increasingly inaccurate.

223−3.5.14.2 Check on Discharge Rate. The success of the trickle−discharge routine is highly dependent on the accuracy of the ammeter being used and the attention given to monitoring the discharge rate. Meter accuracy and proper maintenance of the trickle−discharge routine can be verified when pilot cell specific gravity readings, taken at the same time each day, show at least a three point drop per day or a 21 point drop per week. This verification should be made weekly using the daily pilot cell readings. If the specific gravity drop is not 21 points per week, increase attention to monitoring the rate. If the proper 21 point drop is still not verified after the second week, increase the indicated trickle−discharge rate in two amperes increments until a three point drop per day is verified. Calibrate ammeter at first opportunity.

223−3.5.15 SEMIANNUAL CAPACITY TEST DISCHARGE. See paragraph 223−5.5.4. The capacity discharge rate for lead−calcium grid batteries is checked at the 3−hour rate. Lead−calcium batteries must demonstrate 90 percent of rated capacity.

223−3.5.16 ELECTROLYTE AGITATION SYSTEM. Uniformity in specific gravity and temperature throughout the electrolyte in each cell of all types of lead acid batteries is critical for obtaining full battery capacity and achieving extended service life. The electrolyte air agitation system on all submarines should be operated at all times to obtain maximum benefit (paragraph 223−1.9.15). Normal battery operation is permitted if the electrolyte agitation system malfunctions for the entire battery or for individual cells; however, the agitation system should be repaired and placed in operation as soon as possible to avoid loss of battery service life and capacity. These losses will occur at a faster rate in lead−calcium batteries since these receive fewer gassing charges and less electrolyte agitation by gas bubbles than do lead−antimony batteries.

223−3.5.16.1 Securing of the Battery Electrolyte Agitation (BEA) System. The electrolyte agitation system on all submarines should be operated continuously. However, for reasons of scheduled preventive maintenance, overhaul or other conditions of shipyard maintenance, where it is necessary and required, the BEA may be secured. Only under limited circumstances should the BEA be secured for a period exceeding 24 hours. The BEA system may be secured for extended maintenance activity provided the system has been in continuous operation for a period not less than 72 hours, with the battery on open circuit. When it is necessary to secure the system the following guidelines shall be followed:

a. The BEA systems should not be indiscriminately secured. Secure the BEA system only when necessary and required.

b. Schedule required work/re−work so that the BEA system is secured for as short a duration of time as possible, in any event agitation should be restored within 24 hours.

c. During the time the BEA is secured, electrical drain on the ship’s battery should be minimized and kept only to essential loads for the duration of the secured period.

d. <u>NO battery charging</u> should occur during the secured period.

e. The BEA system should be placed back in operation immediately following completion of the scheduled task, this period of time is not to exceed 24 hours.

f. Upon resumption of BEA system operation, verify that there has been <u>NO change</u> to the airflow/pressure setting of the BEA system.

g. Before doing a battery charge, following periods where the BEA system has been secured, ensure that the BEA system has been in operation for a minimum of 24 hours prior to initiation of the battery charge.

h. Ship’s force should record the time period that the BEA system was inoperative in the ship’s battery log.

223−3.6 BATTERY OPERATION DURING NEW CONSTRUCTION, OVERHAUL AND EXTENDED AVAILABILITY

223−3.6.1 GENERAL. Normal battery operating procedures are dictated in part by submarine power requirements while underway or during in−port periods where underway readiness must be maintained. Many operating procedures are developed to support these requirements and are not necessarily due to battery limitations and characteristics. During periods of new construction, overhaul and extended availability, submarine power requirements are reduced and the nuclear reactor cooled down, with ship's loads supported by shore power. Meanwhile, the main storage battery is normally maintained fully charged on open circuit and is not used except in specific support of tests or in emergencies. During these periods, battery and battery support system operations are made more flexible to avoid unnecessary interference with shipyard work and are otherwise dictated only by the electrochemical characteristics of lead acid batteries.

223−3.6.2 AUTHORITY FOR REDUCED OPERATING REQUIREMENTS AND CONCURRENCE ON DEVIATIONS. During new construction, the Supervisor of Shipbuilding is responsible for ensuring that battery operations are in accordance with requirements in paragraphs 223−3.6.3 through 223−3.6.5. During new construction after ship's force takes operational control of the battery, or during overhaul or extended availability, the submarine Force Commander grants authority for reduced operating requirements and ship's force is made responsible for ensuring that battery operations are in accordance with the following paragraphs. When shipyard conditions necessitate deviation from the following procedures, the Supervisor of Shipbuilding or ship's force shall request concurrence from NAVSEA who will, if necessary, obtain the battery manufacturer's concurrence. To avoid unnecessary delays, concurrence on deviations may be obtained via telephone, documented as required. All deviations from prescribed procedures shall be entered in the battery record book.

223−3.6.3 GENERAL OPERATION. Battery operation shall be in accordance with paragraphs 223−3.1 through 223−3.5, except as modified by paragraphs 223−3.6.3.1 through 223−3.6.5.

223−3.6.3.1 Ventilation. Battery ventilation requirements shall be in accordance with Section 4. For hydrogen monitoring, see paragraph 223−4.2.4.

223−3.6.3.2 Electrolyte Agitation System. The electrolyte air agitation system shall be operated as follows for all battery types:

a. The system may be secured when the battery is being maintained fully charged on open circuit with battery disconnects open or with disconnects closed and the battery in intermittent service.

b. The system must be operated continuously if the battery is the basic power source for hotel loads or is in the trickle−discharge mode of operation. If the normal source of air is not available to support this requirement, a temporary air source must be provided.

c. The system shall be in continuous operation for at least 24 hours prior to each equalizing charge. The required 24−hour period shall start after completion of a functional check of all cell agitators as described in paragraph 223−5.4.2. A system malfunction shall be corrected in accordance with paragraphs 223−5.4.3.1 through 223−5.4.3.3 and 223−6.8.

223−3.6.4 BATTERY CHARGES. No special charge is required after installation except that the first charge given onboard ship shall be an equalizing charge (see section 223−3.2.8, paragraphs b and c). An equalizing charge is also given prior to entering any extended availability or overhaul period longer than 30 days. If this period is three months or less, normal oper−

ations can be resumed without additional charging.

If longer, an equalizing charge must be conducted prior to resuming normal trickle−discharge operation. Battery charging for USS DOLPHIN may be reviewed in USS DOLPHIN Battery technical manual. Otherwise, battery charging shall be as follows:

a. Open Circuit Mode. In the open circuit mode of operation, or when the battery is on open circuit operation and periodic use results where there are fewer than 1000 Ah for GUPPY I Mod C, 1400 Ah for GUPPY I Mod E and 2000 Ah for TRIDENT of discharge. An equalizing charge must be given between the sixth and seventh month. If shipyard work will interfere with this schedule, an equalizing charge must be conducted prior to the start of work. Cell voltages and specific gravities shall be plotted for each equalizing charge and compared to plots of previous equalizing charges. Any unexplained change in the average value, or any individual deviations from the average value, shall be investigated.

b. Open Circuit − Intermittent Service Mode. In this mode of operation, the battery is on open circuit and periodic use result in 1000 Ah for GUPPY I Mod C, 1400 Ah for GUPPY I Mod E and 2000 Ah for TRIDENT or more of discharge. In this case, an equalizing charge must be given within 30 days after reaching 1000 Ah GUPPY I Mod C, 1400 Ah GUPPY I Mod E or 2000 Ah TRIDENT or when use results in 3000 Ah (6000 Ah for TRIDENT) of discharge, or when specific gravity drops to 1.195, whichever occurs first. Cell voltages and specific gravities shall be plotted for each equalizing charge and compared to plots of previous equalizing charges. Any unexplained change in the average value, or any individual deviations from the average value, shall be investigated.

c. Trickle−discharge Mode. In the trickle−discharge mode of operation, the battery is connected to the busbars and continuously discharged at four to seven amperes for GUPPY I Mod C, five to 10 amperes for GUPPY I Mod E and seven to 14 amperes for TRIDENT and is available for additional discharge as required. A charge is given every two weeks, or when cumulative Ah discharge reaches 4000 Ah for GUPPY I Mod C, 5400 Ah for GUPPY I Mod E and 7500 Ah for TRIDENT, or when specific gravity drops to 1.175 for GUPPY I Mod C and TRIDENT’s or 1.185 for GUPPY I Mod E, whichever occur first. These charge criteria assume that residual capacity considerably below rated capacity can be tolerated. If a higher residual capacity is required, charge criteria may be adjusted accordingly. If a biweekly routine is maintained, every other charge should be an equalizing charge. Charging more frequently than once a week should be avoided; equalizing charges should not be given more often than once a month.

223−3.6.5 TEST DISCHARGES. Semi−annual battery capacity test discharges are not normally required during new construction, overhaul or extended availability periods. If a test discharge is required, it is conducted in accordance with paragraph 223−5.5.4. Low capacity (below 90 percent) is common after a battery replacement or after a period of extended inactivity. Capacity will increase when the battery is placed in normal service.

SECTION 4.
VENTILATION

223−4.1 BATTERY COMPARTMENT VENTILATION SYSTEM DESIGN PRINCIPLES

223−4.1.1 PURPOSE OF BATTERY COMPARTMENT VENTILATION. Potentially hazardous gasses are generated by the charging and discharging of lead acid batteries. Of these gasses, hydrogen, which is highly explosive, presents the greatest problem to the submarine designer and the ship's crew. The battery compartment exhaust system is designed to keep the hydrogen concentration in the battery compartment below the lower explosive limit. With proper operation and maintenance, the battery compartment exhaust system can maintain a safe hydrogen concentration in the battery compartment under all modes of operation.

223−4.1.2 HYDROGEN FORMATION IN SUBMARINE BATTERIES. Hydrogen is formed in lead acid batteries through the electrolysis of water. The hydrogen generation rate is dependent upon the following factors:

a. The charging rate

b. The number of cells in the battery

c. The point (in time) in the charging process.

Hydrogen is generated very slowly when the battery is on open-circuit, when it is discharging and during most of a battery charge. However, as the battery approaches full charge the hydrogen generation rate increases rapidly. As the battery approaches full charge, it becomes increasingly difficult for it to store additional electrical energy. For this reason, excess energy begins to electrolyze water (in the electrolyte solution) into hydrogen and oxygen. When the battery becomes fully charged, all of the charging current is used for electrolysis. At this point, the battery is said to be fully gassing. (see sections 223−3.2.8, paragraph b, and 223−3.2.6.3)

223−4.1.2.1 Hydrogen Generation Rate. When a battery is fully gassing, the hydrogen generation rate is a function of the finishing rate and the number of cells in the battery. For a fully charged (i.e., fully gassing) battery, the theoretical hydrogen generation rate, H, is defined by the equation:

$$H = 0.00027(I)(N) \quad (1)$$

Where: H = the theoretical hydrogen generation rate, in cubic feet per minute (cfm)

I = the battery finishing rate, in amperes

N = the number of cells in the battery.

NOTE

> To facilitate references to equations within the text, all important equations are numbered, in parentheses, at the right of the equation. Also, a list of variables used in this section can be found at the end of the text.

The derivation of equation (1) can be found in the NAVSEA Submarine Ventilation

System Design Manual, publication S9512−A2−MMO−010.

223−4.1.2.2 Effects of Barometric Pressure on the Hydrogen Generation Rate. During a battery charge, hydrogen can be found in three locations within a battery cell:

a. On the walls and plates of the cell

b. In the electrolyte solution

c. In the space between the electrolyte and the cell top.

When the barometric pressure within the submarine is reduced, the quantity of hydrogen which can adhere to surfaces within the cell or remain dissolved within the electrolyte is greatly reduced. Therefore, the rate at which hydrogen is released by the battery increases (even though the rate at which hydrogen is generated is not affected by the pressure reduction). Therefore, the hydrogen generation rate appears greater than it actually is. Since the barometric pressure within the ship drops during snorkel operations (due to the cycling of the snorkel head valve), provisions must be made for diluting the additional hydrogen released by the battery during snorkel operations.

223−4.1.2.3 Hydrogen Generation Rate While Snorkeling. To account for the additional hydrogen released by the battery during snorkel operations, an equivalent charging rate, I_S, is added to the battery finishing rate, I. For snorkel operations, equation (1) becomes:

$$H_S = 0.00027(I + I_S) \qquad (2)$$

Where: H_S = the hydrogen generation rate while snorkeling, in cubic feet per minute (cfm)

I_S = the equivalent battery charging rate (i.e., that finishing rate which causes the battery to generate hydrogen at the same rate as the barometric pressure reduction experienced during snorkel operations does), in amperes.

NOTE

The equivalent charging rate, I_S, can only be determined through testing. (see section 223−4.6.8) Based on previous tests, I_S is assigned a value of 100 amperes per operating diesel engine.

223−4.1.2.4 Hydrogen Generation During Recurring Pressure Reductions. After a period of reduced barometric pressure, conditions within the battery cells (i.e., the amount of hydrogen within the electrolyte, on the cell walls and plates, and within the head space) will return to normal. During this normalization period, the amount of hydrogen released by the battery is substantially reduced. Therefore, when several pressure reductions occur within a short period of time, the battery’s hydrogen release rate only increases during the first pressure reduction. Hydrogen is released at a greater-than-normal rate only when the barometric pressure within the ship falls below the level reached during a previous pressure reduction. However, for safety, a constant hydrogen release rate (see section 223−4.1.2.3) should be assumed whenever the ship is snorkeling.

223−4.1.3 MAXIMUM SAFE CONCENTRATION OF HYDROGEN IN AIR. Any concentration of hydrogen between four and 75 percent (in air) will explode when ignited. Therefore, the maximum concentration of hydrogen permitted at any point within the battery compartment is 3.0 percent. To ensure that pockets of hydrogen do not form in other areas of the ship, the NAVSEA Nuclear Powered Submarine Atmosphere Control Manual, publication S9510−AB−ATM−010 (Confidential), states that the ship's ambient hydrogen concentration should not exceed 1.0 percent. The shipboard hydrogen detector and the Central Atmosphere Monitoring System (CAMS) should be operated continuously to ensure that the allowable hydrogen concentration limits are not exceeded.

223−4.1.4 PRINCIPLES OF BATTERY COMPARTMENT VENTILATION. Battery compartment exhaust systems are draw-through systems. That is, air is pulled through the battery compartment by exhaust fans, low-pressure blower or diesel located on the exhaust side of the battery compartment. In general, the battery compartment exhaust system consists of: a Navy standard air filter, a high-efficiency particulate air (HEPA) filter or an electrostatic precipitator (ESP), an electric duct heater, an inlet isolation valve, a natural supply duct, a supply air distribution plenum, an exhaust plenum, exhaust ductwork, an outlet isolation valve, a hydrogen detection system, a battery airflow meter, a CAMS sampling port, battery exhaust fan(s), a battery exhaust emergency relief (BEER) damper, and diverting valves or dampers to direct the airflow to a fan room fan, low-pressure blower or diesel. A CAMS sampling port is provided near the Navy standard air filter at the air inlet of the battery compartment exhaust system to measure the concentration of recirculated hydrogen. A typical battery compartment ventilation system is shown, schematically, in Figure 223−18.

223−4.1.4.1 Air Supply for Battery Compartments. To ensure that the battery compartment is ventilated at all times, the battery compartment exhaust system has several air movers. In addition to the battery compartment exhaust fan(s), a fan room exhaust fan, diesel or low-pressure blower can be used to ventilate the battery compartment. Supply air is drawn into the battery compartment from an adjacent space via a natural supply duct and a appropriately designed air distribution plenum. A Navy standard filter and a HEPA filter (or an electrostatic precipitator), installed in the natural supply duct, ensure that only clean air is drawn into the battery compartment. An electric duct heater is installed in the natural supply ductwork to reduce the amount of condensation occurring in the battery compartment. Control of dirt and moisture is necessary to prevent battery grounds.

WARNING

The battery compartment electric duct heater and electrostatic precipitator must be deenergized before starting a battery charge. It must remain deenergized throughout the charging operation and for at least 20 minutes after the charge has been secured.

223−4.1.4.2 Battery Compartment Exhaust Arrangements. The battery compartment exhaust system is arranged so that the battery exhaust fan(s) are operated in series with a fan room exhaust fan, low-pressure blower or diesel. When the system is operating in the Recir-

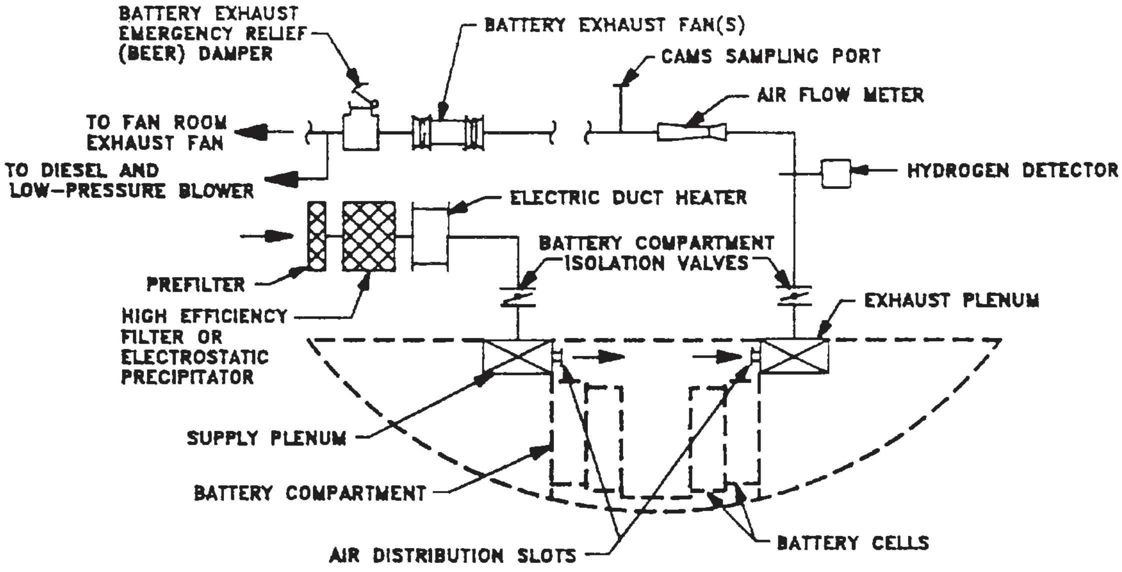


Figure 223–18. Typical Battery Compartment Ventilation System

culate mode, the battery exhaust fan(s) and fan room exhaust fan are run at FAST speed to ventilate the battery compartment. To ensure continuous operation, the battery exhaust fan(s) are powered from the ship's service ac vital bus. In addition, the battery compartment exhaust system can be realigned so that the ship's diesel or low-pressure blower can be used to ventilate the battery compartment. When snorkeling, the battery compartment exhaust system utilizes the battery exhaust fan(s) and the ship's diesel. In the Ventilate mode, the battery compartment exhaust system utilizes the battery exhaust fan(s) and the ship's low pressure blower. In the Surface Ventilate mode, the battery exhaust fan(s) are utilized to ventilate the battery compartment to the fan room.

223–4.1.4.3 Airflow Distribution Within the Battery Compartment. Since hydrogen is lighter than air, it rises from the battery cells to the battery compartment overhead. To prevent the accumulation of hydrogen, the battery compartment exhaust system sweeps the hydrogen-rich air from the battery compartment overhead. The battery compartment air distribution plenums (both supply and exhaust) are carefully designed and installed to ensure that the air distribution within the battery compartment is uniform.

223–4.1.4.4 Air Distribution Plenums. The battery compartment air distribution plenums (supply and exhaust) are located along opposite, long sides of the battery compartment. A slot or series of slots, running the entire length of each plenum, uniformly distributes the airflow. Both plenums are designed so that the static pressure is equal at all points in the plenum. During construction of OHIO Class submarines, the airflow through the slots is balanced by adjusting the slot width. This ensures that the hydrogen-free ventilation air mixes thoroughly with the hydrogen-rich air inside the battery compartment. By providing a sufficient quantity of uniformly distributed airflow within the battery compartment, the ventilation system prevents explosive concentrations of hydrogen from accumulating in corners, at structural members or at other natural flow barriers within the battery compartment.

223−4.1.4.5 Battery Exhaust Emergency Relief (BEER) Damper. The battery exhaust emergency relief (BEER) damper is a gravity-loaded, flapper-type damper. The BEER damper is mounted in the battery compartment exhaust ductwork downstream of the battery exhaust fan(s) and upstream of the first isolation valve after the fan(s). In this location, the BEER damper can maintain airflow through the battery compartment at all times. The BEER damper is normally located in the fan room or similar location to ensure the rapid dilution or elimination of any exhausted hydrogen. In no case should the BEER damper be located near a possible source of ignition.

223−4.1.4.6 Hydrogen Distribution Factor, K. The hydrogen distribution factor, K, is defined as the ratio of the highest measured hydrogen concentration in the battery compartment to the hydrogen concentration in the battery exhaust duct. Mathematically,

$$K = \frac{C_h - C_o}{C_e - C_0} \qquad (3)$$

Where: K = the hydrogen distribution factor, dimensionless

C_h = the highest measured hydrogen concentration in the battery compartment, in percent. For safety, C_h cannot exceed 3.0 percent. (see section 223−4.1.3)

C_o = the hydrogen concentration at the inlet of the battery compartment, in percent. (When there is no CAMS sampling port at the inlet, C_o can be assumed to be equal to the ship's ambient concentration.)

C_e = the hydrogen concentration of the air in the battery compartment exhaust ductwork, in percent.

The hydrogen distribution factor is dependent upon the characteristics of each ship's battery compartment and battery compartment exhaust system. Therefore, the hydrogen distribution factor for any particular ship or ship class can only be determined by testing. (see section 223−4.6.7)

NOTE

When the actual value of K (determined through testing) is less than 2.0, the hydrogen distribution factor is assigned a value of 2.0. When the value of K (determined through testing) is greater than 2.0, the actual value should be used.

223−4.1.5 HYDROGEN DISPOSAL. When a submarine is operating submerged, hydrogen is burned in the CO-H_2 burners. During surfaced or snorkel operations, the diesel or low-pressure blower can be used to ventilate the battery compartment directly overboard. In the Surface Ventilate mode, if the topside hatches are open, the main induction fan(s) can be used to reduce the hydrogen concentration in the ship's atmosphere

223−4.2 BATTERY COMPARTMENT EXHAUST SYSTEM INSTRUMENTATION

223−4.2.1 AIRFLOW METERS. Battery airflow meters are used to monitor the volumetric airflow rate through the battery compartment. Two types of airflow meters are currently installed in submarines. Venturi-type airflow meters are installed in all submarines, with the exception of OHIO Class. OHIO Class submarines are outfitted with hot-wire anemometer type airflow meters.

223−4.2.2 SHIPYARD INSTALLATION AND CALIBRATION OF VENTURI AIRFLOW METERS. Venturi airflow meters consist of a venturi, a pressure transmitter and a remote indicator. The venturi, which creates a differential pressure directly proportional to the square of the airflow rate, is installed in the battery exhaust duct. The pressure transmitter converts the developed pressure differential to an electrical signal and transmits that signal to the remote indicator. The indicator needle in the remote indicator moves in direct response to the strength of the electrical signal generated by the transmitter. Airflow indicators are calibrated in cubic feet per minute, cfm. The remote indicator for the airflow meter is located on the Electric Plant Control Panel (EPCP).

223−4.2.2.1 Airflow Meter Venturi. The airflow meter venturi is designed to develop a pressure differential of approximately four inches of water, gage, at the design airflow rate. This pressure differential is compatible with the pressure differential specified for the transmitter and the remote indicator, which are designed to indicate full flow at pressures ranging from 3-1/2 to 4-1/2 inches of water, gage. The venturi is located as close to the exhaust plenum as possible.

223−4.2.2.2 Venturi Airflow Meter Pressure Transmitter. The venturi airflow meter pressure transmitter is mounted as close to the venturi as possible. 3/8-inch OD (outside diameter) stainless steel instrument tubing is used to connect the venturi to the transmitter. Tubing is no more than 10 feet in length and all tubing connections are made with flared or silver brazed fittings. Gage valves are provided in each transmitter lead so that a portable U-tube manometer, or magnehelic gage, can be connected to the leads during the instrument calibration procedure. (see section 223−4.2.2.3, step 5) A valved equalizing cross-connect is provided between the gage valves and the transmitter. The equalizing valve is normally shut and to prevent overpressurization of the transmitter diaphragm, should only be opened when removing or installing the transmitter.

223−4.2.2.3 Venturi Airflow Meter Calibration Procedure. When the battery compartment exhaust system installation is complete, the venturi airflow meter should be calibrated in accordance with the following procedure:

1. Using a calibrated venturi, flow nozzle or orifice plate and a manometer, determine the differential pressure developed by the venturi from no flow, up through the flow rate which corresponds to maximum remote indicator needle rotation. A minimum of 10 data points should be recorded and should consist of approximately equally spaced flow rates. If the installed venturi develops a differential pressure greater than or equal to 4-1/2 inches of water, gage, at maximum flow, the downstream pressure tap should be moved upstream by a distance calculated to bring the differential pressure below 4-1/2 inches of water, gage. If the venturi develops a differential pressure less than or equal to 3-1/2 inches of water, gage, at maximum flow, the installed venturi should be replaced by a venturi with a smaller throat diameter.

2. Set the calibrating spring adjustment on the pressure transmitter so that the deflection of the indicator needle is just short of full scale (approximately 240 degrees of arc) at the differential pressure developed by the venturi at maximum airflow. This ensures that the airflow indicator needle will not be “pegged” or off scale at full airflow.

3. Plot on the same graph the data obtained from the testing of both the airflow meter venturi and the transmitter/indicator assembly. That is, plot the airflow rate at which the venturi develops a given differential pressure against the deflection of the airflow indicator needle at that same pressure. Use the resulting calibration curve to mark the air flow indicator.

4. The installation should be inspected for workmanship, tightness and completeness after the entire battery airflow meter system has been installed on the ship. Proper operation should be verified by comparing airflow measurements between the battery airflow meter and measurements taken with a rotating vane anemometer at the Navy standard filter on the air inlet to the battery compartment. Measurements should correspond within 10 percent and should be taken at the maximum airflow rate, the minimum airflow rate (approximately 454 cfm), and three, approximately equal spaced, intermediate air flow rates.

223−4.2.2.4 Use of Calibration Curves. As long as the venturi throat and pressure taps are kept clean and undamaged, the pressure vs. flow characteristics of the venturi airflow meter will remain constant. However, the calibration of the transmitter can change or go out of adjustment. The calibration of the transmitter can be checked easily with a portable manometer and the calibration curves prepared in step 3 of section 223−4.2.2.3. Each submarine should maintain a set of calibration curves for this purpose. The calibration of the venturi airflow meter must be kept as accurate as possible since the safety of the ship and the crew depends on the rapid identification of problems with the battery compartment exhaust system.

223−4.2.3 SHIPYARD INSTALLATION AND CALIBRATION OF HOTWIRE ANEMOMETER-TYPE AIRFLOW METERS. A hot-wire anemometer airflow meter consists of a sensing element, an electronic controller and a remote indicator. The sensing element is mounted in the battery compartment exhaust ductwork where the airflow cools an array of heated thermistors. This cooling effect changes the internal resistance of the thermistors in direct proportion to the airflow velocity. The controller converts this change in resistance to a voltage which is read by the remote indicator. After the airflow meter is installed, the voltages produced by the controller at various airflow rates are recorded. This voltage versus airflow relationship is then used to calibrate the remote indicator in cubic feet per minute (cfm). It is important to note that this voltage versus airflow relationship is only valid for the velocity profile encountered in the duct where the sensing element is installed. Thus, if the location of the sensing element or the configuration of the ductwork is changed, the airflow meter must be recalibrated for the new velocity profile.

223−4.2.4 HYDROGEN DETECTORS AND INDICATORS. The hydrogen detector is used to determine the value of C_e by monitoring the hydrogen concentration in the battery compartment exhaust duct. The relationship between the hydrogen concentration in the battery compartment exhaust, C_e, and the maximum hydrogen concentration in the battery compartment is defined by the hydrogen distribution factor, K. (see section 223−4.1.4.6).

NOTE

> If necessary, hydrogen concentration can be measured by the Central Atmosphere Monitoring System (CAMS).

223−4.2.4.1 Hydrogen Detectors. The hydrogen detector consists of a controller unit, two sensing elements and four remote indicators. Two separate hydrogen detection circuits are provided in each detector unit so that each circuit serves as a backup for the other. In addition, the sensors are wired so that each circuit is energized at all times. Two remote hydrogen indicators (one for each detection circuit) are mounted on both the Electric Plant Control Panel (EPCP) and the Ballast Control Panel (BCP).

223−4.2.4.2 Hydrogen Detector Operation. The hydrogen detectors operate on the principle of thermal conductivity. A heated sensing element is exposed to a sample of air from the battery compartment exhaust duct. As the hydrogen content of the air sample increases, the sample's thermal conductivity also increases and the temperature of the sensing element decreases proportionately. The electrical resistance of the sensor is proportional to its temperature. Therefore, changes in hydrogen concentration can be measured by measuring the changes in the electrical resistance of the sensing element. The hydrogen detector controller unit converts the sensing element's resistance measurement to an electrical output signal. This signal is sent to the remote indicators which are calibrated in percent hydrogen.

223−4.2.4.3 Hydrogen Detector Calibration Procedure. Hydrogen detectors should be calibrated in accordance with the manufacturer's recommendations. When calibrating the hydrogen detectors, only clean, dry, compressed calibration gases (with two known hydrogen concentrations of 0.0 percent and 2.5 percent, respectively) should be used. To ensure that the calibration gases are dry, the bubbler jar in the calibration set should be left empty.

223−4.2.5 CENTRAL ATMOSPHERE MONITORING SYSTEM. A Central Atmosphere Monitoring System (CAMS), capable of monitoring hydrogen as well as several other gasses, is installed on all nuclear submarines. Sampling ports for the CAMS unit are typically located near the inlet to the battery compartment exhaust system (used to measure C¿o¿), in the battery compartment exhaust ductwork, and at several other locations throughout the ship. If the hydrogen detector fails, the CAMS may be used to monitor the hydrogen concentration of the battery compartment exhaust. Percent hydrogen is determined by dividing the hydrogen partial pressure by the total pressure as indicated by the CAMS and multiplying by 100.

223−4.3 BATTERY COMPARTMENT EXHAUST SYSTEM DESIGN LIMITS

223−4.3.1 HYDROGEN CONCENTRATION LIMITS. The hydrogen concentrations of the battery compartment and the ship's atmosphere may be affected by any of the following:

a. The number of cells in the battery

b. The battery charging (or discharging) rate

c. The point (in time) in the charging procedure

d. The sudden reduction of ambient barometric pressure

e. The battery ventilation rate

f. The number and type of CO-H_2 burners operating

g. The termination point of the battery compartment ventilation system (i.e., inboard or overboard).

Since the concentration of hydrogen at any location within the ship is subject to so many variables, the following hydrogen concentration limits have been established:

a. The maximum allowable hydrogen concentration at any point within the battery compartment, C_{max}, cannot exceed 3.0 percent (see section 223−4.1.3)

b. The ambient hydrogen concentration in the ship's atmosphere, C_o, cannot exceed 1.0 percent (see section 223−4.1.3)

c. The maximum allowable hydrogen concentration in the battery compartment exhaust duct (i.e. at the hydrogen detector) is calculated by solving equation (3) for C_e and using the actual value of C_o:

$$C_e = C_o + \frac{(3 - C_o)}{(K)}$$

Thus, for a submarine with a K−factor of 2 and no recirculated hydrogen, $C_{e,max}$ = 1.5 percent. If recirculated hydrogen is present and C_o is known (i.e., as read from CAMS), $C_{e,max}$ could conceivably go as high as 2.0 percent (with C_o = 1 percent).

To ensure that the hydrogen concentration within the battery compartment remains at a safe level, the hydrogen concentrations listed above (both C_o and C_e) should be monitored at regular intervals.

223−4.3.1.1 Hydrogen Concentration of Battery Compartment Ventilation Air. Since the battery is the primary source of hydrogen on a submarine, the hydrogen concentration in the battery compartment will be greater than that in other areas of the ship. The increase in the average concentration of hydrogen in the ventilation air moving through the battery compartment can be calculated as follows:

$$C_g = \frac{100\ H}{Q} \qquad (4)$$

Where: C_g = the increase in the average hydrogen concentration of the battery compartment ventilation air due to hydrogen generated by the ship's battery (i.e., the concentration increase across the battery compartment), in percent

Q = the battery compartment ventilation rate, in cubic feet per minute (cfm).

NOTE

The constant (100) in equation (4) is used to convert the calculated hydrogen concentration from a decimal fraction to a percentage.

Substituting the hydrogen generation rate, H, developed in equation (1) into equation (4) yields:

$$C_e = \frac{100(0.00027)(I)(N)}{Q}$$

$$= \frac{0.027(I)(N)}{Q} \qquad (5)$$

Since the volumetric airflow rate through the battery compartment is constant, the average hydrogen concentration gained by the air moving through the battery compartment, C_o, can also be calculated by subtracting the hydrogen concentration of the ambient air entering the compartment, C_o, from the hydrogen concentration of the exhaust air stream, C_e. Expressed mathematically:

$$C_g = C_e - C_o \qquad (6)$$

By combining equations (5) and (6), it follows that:

$$C_e - C_o = \frac{0.027(I)(N)}{Q} \qquad (7)$$

223−4.3.1.2 Hydrogen Concentration of the Ship's Atmosphere. The hydrogen concentration of the ship's atmosphere (in any space or compartment other than the battery compartment) is referred to as the ambient hydrogen concentration. The ambient hydrogen concentration is, for all practical purposes, the same at all locations. When operating with the hatches sealed, the CO-H_2 burners operating, and the main storage battery discharging or on open-circuit, the ambient hydrogen concentration within the ship will drop, over time, and approach zero percent. During a battery charge, the ambient hydrogen concentration will rise. (see section 223−4.1.3)

223−4.3.1.3 Equilibrium Hydrogen Concentration During Battery Charging. The factors affecting the hydrogen generation rate, H, are listed in section 223−4.1.2. The factors affecting the hydrogen removal rate are as follows:

a. The type of CO-H_2 burners installed on the ship

b. The number of CO-H_2 burners operating

c. The efficiency of the CO-H_2 burners

d. The ambient hydrogen concentration.

Equilibrium is reached when the amount of hydrogen consumed by the CO-H_2 burners equals the hydrogen generated by the battery. Stated mathematically, equilibrium is reached when:

$$H = (Q_b)(N_b)(\eta_b/100)(C_o)/100)$$

Q_b = The airflow rate through each CO-H_2 burner, in cfm. For Mk. IV burners, Q_b = 500 cfm. For Mk. V burners, Q_b = 650cfm

N_b = The number of operating CO-H_2 burners

η_b = The efficiency of the installed CO-H_2 burners. Unless specified otherwise,
η_b = 90 percent.

NOTE

The constant (100) which appears twice in the equation above is used to convert the values of η_b and C_o from percentages to decimal fractions.

The ambient hydrogen concentration at equilibrium can be determined by solving the previous equation for C_o. For simplicity, the product of the first three terms in the right-hand side of the equation are defined as the effective burner airflow rate, R. Therefore, the ambient hydrogen concentration at equilibrium can be calculated as follows:

$$C_o = \frac{100H}{R} \qquad (8)$$

Where: R = The effective burner airflow rate, in cfm

$= (Q_b)(N_b)(\eta_b/100)(C_o)/100)$

223−4.3.1.4 Calculating the Time Required to Reach Equilibrium. The change in ambient hydrogen concentration, dC_o, with respect to time, dt, can be expressed as the rate at which hydrogen is added to the ship's atmosphere minus the rate at which hydrogen is removed from the ship's atmosphere. Expressed as a differential equation:

$$\frac{dC_o}{dt} = \frac{H}{V} - \frac{RC_o/100}{V}$$

$$= \frac{H - RC_o/100}{V}$$

Where: V = the ship's floodable volume, excluding the reactor compartment and access and escape trunks, in cubic feet.

NOTE

The value of V, the ship's floodable volume, can be obtained from the Nuclear Powered Submarine Atmosphere Control Manual, NAVSEA S9510−AB−ATM−010 (Confidential).

By rearranging and integrating this equation, the time to reach equilibrium can be calculated. Theoretically, equilibrium can only be reached after an infinite amount of time (i.e., t = infinity). In practical terms, the change in the ambient hydrogen concentration is minimal after a relatively short period of time. The time required to reach 99 percent of the equilibrium hydrogen concentration can be defined as follows:

$$t = (V/R)\{\ln(H) - \ln[H - (R)(0.99\ C_o/100)]\} \quad (9)$$

Where: ln = natural logarithm.

By rearranging equation (9), the theoretical ambient hydrogen concentration, C_o, can be calculated for anytime, t, after the battery has begun gassing fully. Solving equation (9) for C_o yields:

$$C_o = (H/R)[1 - e^{(-Rt/V)}](100) \quad (10)$$

Where: e = the base of the natural logarithms

= 2.7183.

Example No. 1

Determine the equilibrium ambient hydrogen concentration and time required to reach equilibrium for a LOS ANGELES Class (SSN 688) submarine with the following operating characteristics:

I = 200 amperes

N = 126 cells

V = 160,000 cubic feet (This is not the actual volume. This value is used only for the purpose of this example.)

Q_b = 500 cfm

N_b = 2 burners

η_b = 90 percent

From equation (1):

H = 0.00027(I)(N)

= 0.00027(200)(126)

= 6.804 cfm

By definition:

$$R = (Q_b)(N_b)(\eta_b/100)$$

$$= (500)(2)(90/100)$$

$$= 900 \text{ cfm}$$

Finally, the ambient hydrogen concentration at equilibrium can be calculated from equation (8), as follows:

$$C_o = 100H/R$$

$$= 100(6.804\text{cfm})/900\text{cfm}$$

$$= 0.756 \text{ percent}$$

NOTE

> The ambient hydrogen concentration is less than the maximum allowable ambient concentration of 1.0 percent. (see section 223−4.1.3)

The elapsed time between the time at which the battery begins to gas at its full, theoretical rate and the point at which equilibrium is reached in the ship's atmosphere is calculated by solving equation (9) for the known conditions, as follows:

$$t = (V/R)\{\ln(H) - \ln[H - (R)(0.99C_o)/100]\}$$

$$= (160{,}000/900)\{\ln(6.804) - \ln[6.804 - (900)(0.99)(0.756)/100]\}$$

$$= 819 \text{ minutes or; } 13 \text{ hours, } 39 \text{ minutes.}$$

The preceding value is based on a constant hydrogen generation rate and continuous operation of the CO-H_2 burners. Since it is unlikely that a battery charge would be continued for nearly 14 hours beyond the point at which the battery is fully gassing, it is unlikely that the ambient hydrogen concentration will ever rise to the theoretical value ($C_o = 0.756$ percent) calculated above.

223−4.3.2 BATTERY COMPARTMENT VENTILATION REQUIREMENTS. For safety, battery compartment ventilation must be maintained at all times. The ventilation rate required at any given time depends upon the condition and use of the battery. To ensure the safety of the ship and crew, the battery ventilation rate should be monitored at regular intervals.

WARNING

> Before starting a battery charge, the operation of all ventilation fans, the low-pressure blower and the diesel should be verified for the ventilation line-up under which the battery charge is to be conducted. The position of all ventilation system valves and dampers should be verified to be in accordance with the ship's operating procedures.

223−4.3.2.1 Ventilation Requirements During Battery Charging. In order to conduct a battery charge, some minimum ventilation rate must be provided by the battery compartment exhaust system. This required minimum ventilation rate is calculated by combining equations (3) and (7) as follows:

$$K = \frac{C_h - C_o}{\left[\frac{0.027(I)(N)}{Q}\right]}$$

Replacing C_h with C_{max} in the equation above and solving for the required ventilation rate, Q, the equation becomes:

$$Q_{min} = \frac{0.027(I)(N)(K)}{(C_{max} - C_o)} \qquad (11)$$

Where: Q_{min} = the minimum required battery compartment ventilation rate while battery charging; in cubic feet per minute (cfm). It should be noted that equation (11) is used to determine the minimum required battery compartment ventilation rate, Q_{min}, for known values of C_o.

NOTE

The maximum allowable ambient hydrogen concentration within the ship, C_o, is 1.0 percent. (see section 223−4.1.3)

The required minimum battery compartment ventilation rate should be established at least 20 minutes prior to the beginning of the battery charging operation. Ventilation should be maintained at that same rate throughout the entire charging operation and for at least 20 minutes after the charge has been secured.

WARNING

Personnel are prohibited from opening the battery compartment access or from entering the battery compartment during a battery charge. If battery compartment ventilation is interrupted or reduced for any reason, the battery charge must be secured immediately and an emergency alignment or alternative source of ventilation found. (see section 223−4.4)

Since the ship's hydrogen detector is located in the battery compartment exhaust duct, it is more convenient to have the minimum required battery compartment ventilation rate, Q_{min}, stated in terms of C_e. This relationship can be determined by combining equations (3), (5) and (6), with C_e replaced by C_{max} in equation (3). Solving for Q_{min} yields:

$$Q_{min} = \frac{0.027(I)(N)(K-1)}{(C_{max} - C_e)} \qquad (12)$$

As desired, this equation states Q_{min}, the exhaust airflow rate, in terms of C_e, which can be measured by the ship's hydrogen detector.

NOTE

In equations (11) and (12) the maximum allowable hydrogen concentration at any point within the battery compartment, C_{max}, is 3.0 percent. (see section 223−4.1.3)

223−4.3.2.2 Ventilation Requirements for Battery Charging While Submerged. For submerged operations, the minimum battery ventilation rate is calculated using equation (11). Since all of the hydrogen generated by the ship's battery is recirculated when the ship is submerged, the ambient hydrogen concentration, C_o, should be assigned a worst case value of 1.0 percent. (see section 223−4.3.1)

223−4.3.2.3 Ventilation Requirements for Battery Charging While Surfaced. For surfaced operations, like submerged operations, the minimum battery ventilation rate is calculated using equation (11). However, during surfaced operations, the battery ventilation system can be aligned for either inboard or overboard discharge of the battery compartment exhaust air. If the ventilation system is aligned for inboard discharge, a value of 1.0 percent should be used for the ambient hydrogen concentration, C_o. If the ventilation system is aligned for overboard discharge, the ambient hydrogen concentration is (or is trending to) zero percent. Therefore, a value of 0.0 percent should be used to calculate the minimum safe battery compartment ventilation rate.

223−4.3.2.4 Ventilation Requirements for Battery Charging While Snorkeling. The minimum battery compartment ventilation rate for battery charging while snorkeling is calculated by adding the equivalent charging rate, I_s, to the charging rate, I, in equation (11). This adjusts the hydrogen release rate to account for the reduced ambient pressure within the hull during depth excursions while snorkeling. (see sections 223−4.1.2.2 through 223−4.1.2.4) Equation (11) becomes:

$$Q_{s,\,min} = \frac{0.027(I + I_s)(N)(K)}{(C_{max} - C_o)} \tag{13}$$

Where: $Q_{s,min}$ = the minimum required battery compartment ventilation rate while battery charging when snorkeling, in cubic feet per minute (cfm).

When calculating the minimum ventilation rate for snorkel operations, the ambient hydrogen concentration, C_o, should be assigned a value of 1.0 percent if the ventilation system is aligned for inboard discharge of the battery compartment ventilation air. If the ventilation system is aligned for overboard discharge, the ambient hydrogen concentration in equation (13) should be assigned a value of 0.0 percent. As stated previously, it is easier to monitor battery compartment safety, if $Q_{s,min}$. is stated in terms of C_e, the hydrogen concentration in the battery compartment exhaust duct. By adding the equivalent charging rate, I_s, to the charging rate, I, in equation (12), that equation becomes:

$$Q_{s,\,min} = \frac{0.027(I + I_s)(N)(K\text{-}1)}{(C_{max} - C_e)} \tag{14}$$

NOTE

Based on previous tests, the equivalent charging rate, I_s, is assigned a value of 100 amperes per operating diesel engine. As in all previous calculations, C_{max} is assigned a value of 3.0 percent.

223−4.3.2.5 Q Versus C Curves for LOS ANGELES Class Submarines, Surfaced or Submerged Operations. The relationships between the battery ventilation rate, Q, and the hydrogen concentration in the exhaust air, C_e, or the hydrogen concentration in the intake air, C_o, can be shown graphically for each operating mode. The resulting (Q vs. C) curves can be used to determine the minimum safe battery ventilation rate. The curves can also be used to determine the maximum value of C_e or C_o permissible for a specific battery ventilation rate. For LOS ANGELES Class submarines:

$K = 2.5$

$I = 200$ amperes

$N = 126$ cells

$C_{max} = 3.0$ percent.

When operating in the surfaced or the submerged modes, the relationship of Q to C_e is defined by equation (12):

$$Q_{min} = \frac{0.027(I)(N)(K\text{-}1)}{(C_{max} - C_e)}$$

$$= \frac{0.027(200)(126)(2.5\text{-}1)}{(3.0 - C_e)}$$

$$= \frac{1020.6}{(3.0 - C_e)} \qquad \text{(E2−1)}$$

For the same operating modes, the relationship of Q to C_o is defined by equation (11):

$$Q_{min} = \frac{0.027(I)(N)(K\text{-}1)}{(C_{max} - C_o)}$$

$$Q_{min} = \frac{0.027(200)(126)(2.5)}{(3.0 - C_o)}$$

$$= \frac{1701}{(3.0 - C_o)} \qquad \text{(E2−2)}$$

The curves defined by equations (E2-1) and (E2-2) are shown on Figure 223−19. The relationship of Q to C_o is given by Curve 1. The relationship between Q and C_e is given by Curve 2. Note that Figure 223−19 is only valid for battery charging on surfaced or submerged LOS ANGELES Class submarines.

Example No. 2

For a LOS ANGELES Class submarine operating submerged, determine the minimum battery ventilation rate for a measured battery compartment exhaust air hydrogen concentration, C_e, of 1.5 percent. From Figure 223−19, Curve 2 (Q vs. C_e), the minimum battery exhaust airflow rate for $C_e = 1.5$ percent is 681 cfm. At this rate, the highest hydrogen concentration in the battery compartment, C_{max}, will be 3.0 percent. For the same ventilation rate, Curve 1 indicates that the hydrogen concentration of the intake air, C_o, will be 0.50 percent. At this ventilation rate, the gain in hydrogen concentration across the battery compartment, $(C_e - C_o)$, is 1.0 percent. Note that the values given for C_o and C_e in this example are within the limits defined in section 223−4.3.1.

223−4.3.2.6 Q versus C Curves for LOS ANGELES Class Submarines, Snorkel Operations. For a LOS ANGELES Class submarine conducting a battery charge while snorkeling, the relationship between C_o, the ambient hydrogen concentration of the air entering the battery compartment, and the battery ventilation rate, Q_s, is determined as follows:

$$Q_{s,\,min} = \frac{0.027(I + I_s)(N)(K)}{(C_{max} - C_e)}$$

$$= \frac{0.027(200 + 100)(126)(2.5)}{(3.0 - C_o)}$$

$$= \frac{2551.5}{(3.0 - C_o)}$$

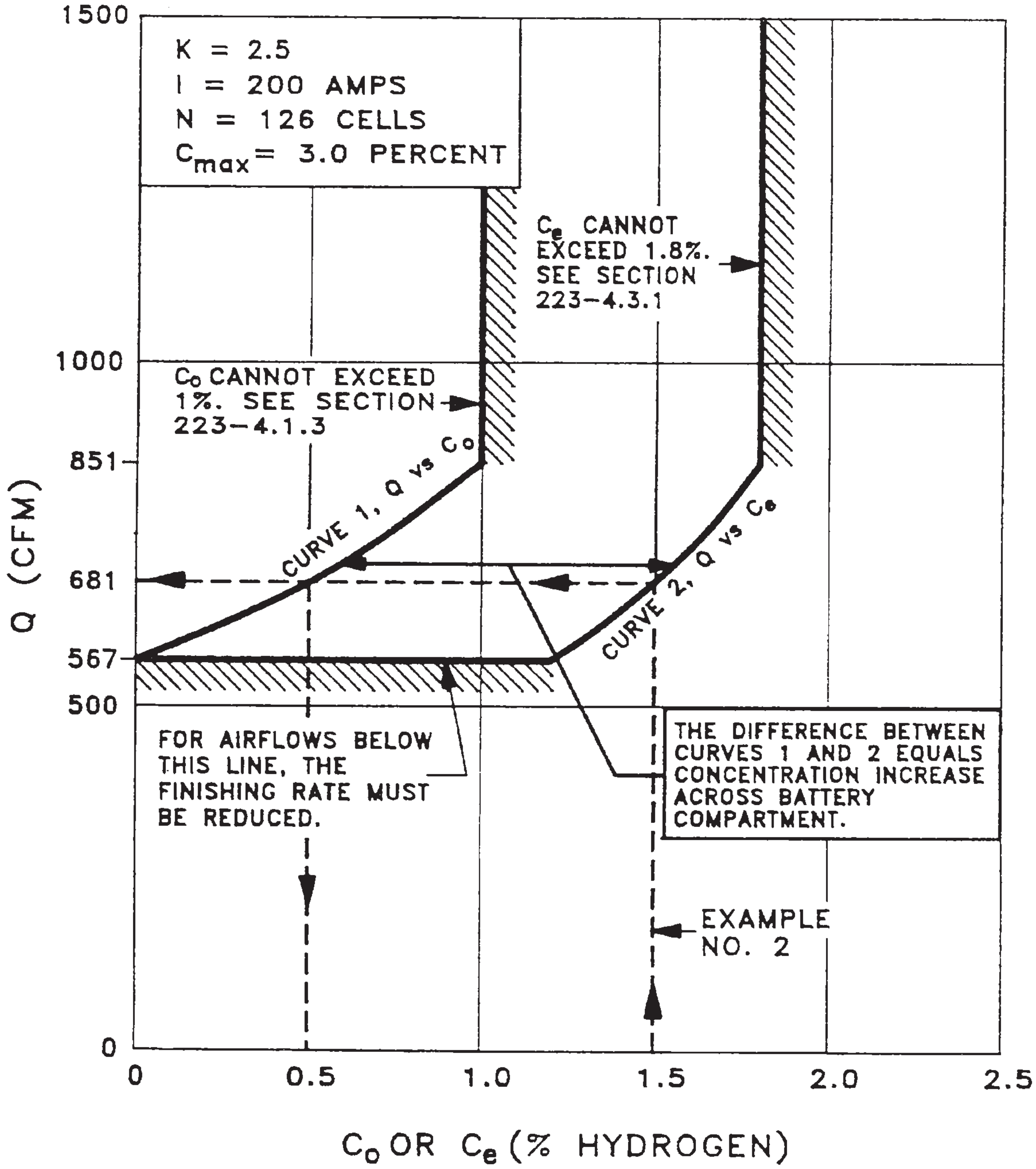


Figure 223−19. Ventilation Airflow Rate vs. C_0 or C_e for Surfaced or Submerged Battery Charging (LOS ANGELES Class Submarines)

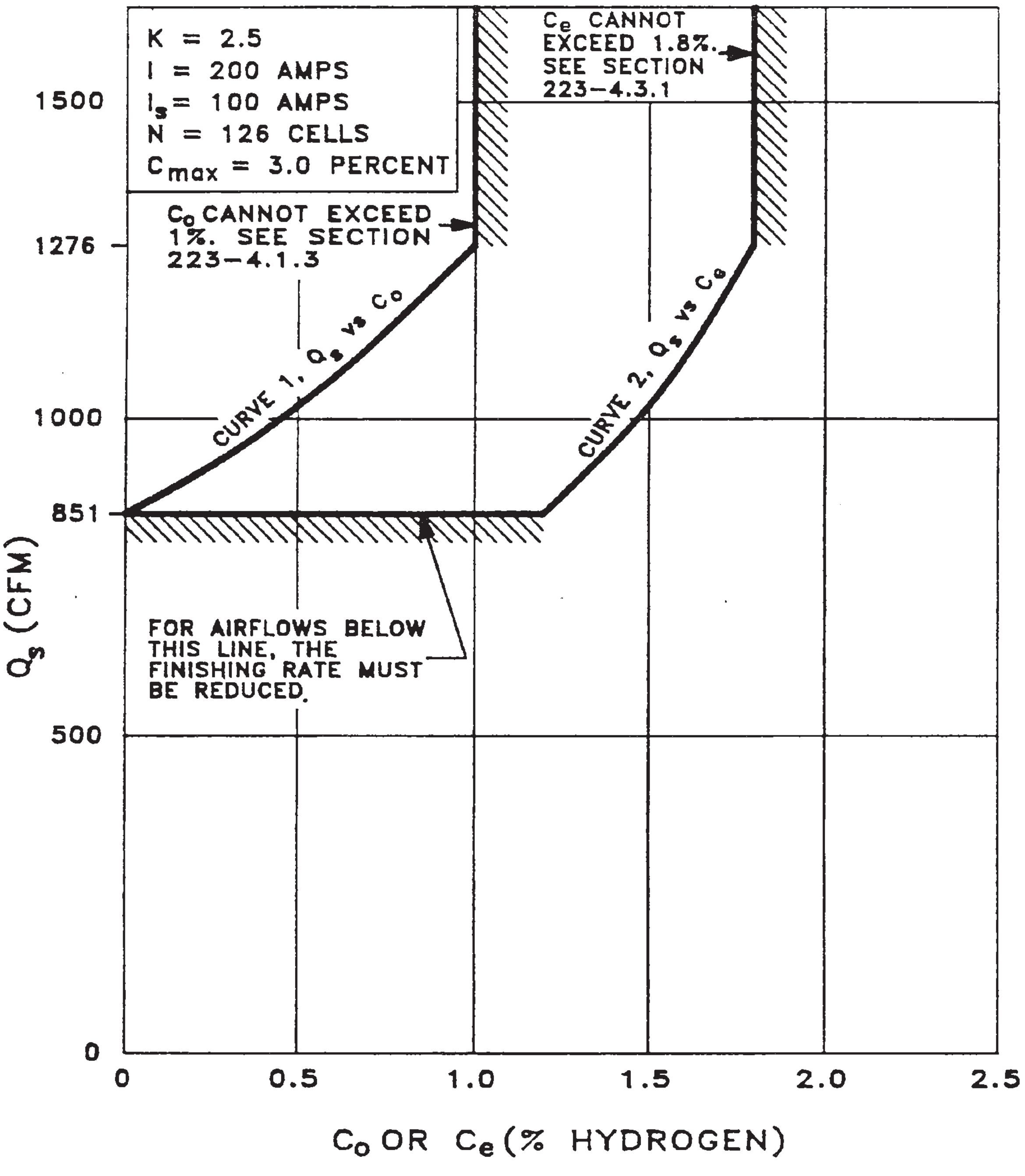


Figure 223−20. Ventilation Airflow Rate vs. C_o or C_e for Battery Charging While Snorkeling (LOS ANGELES Class Submarines)

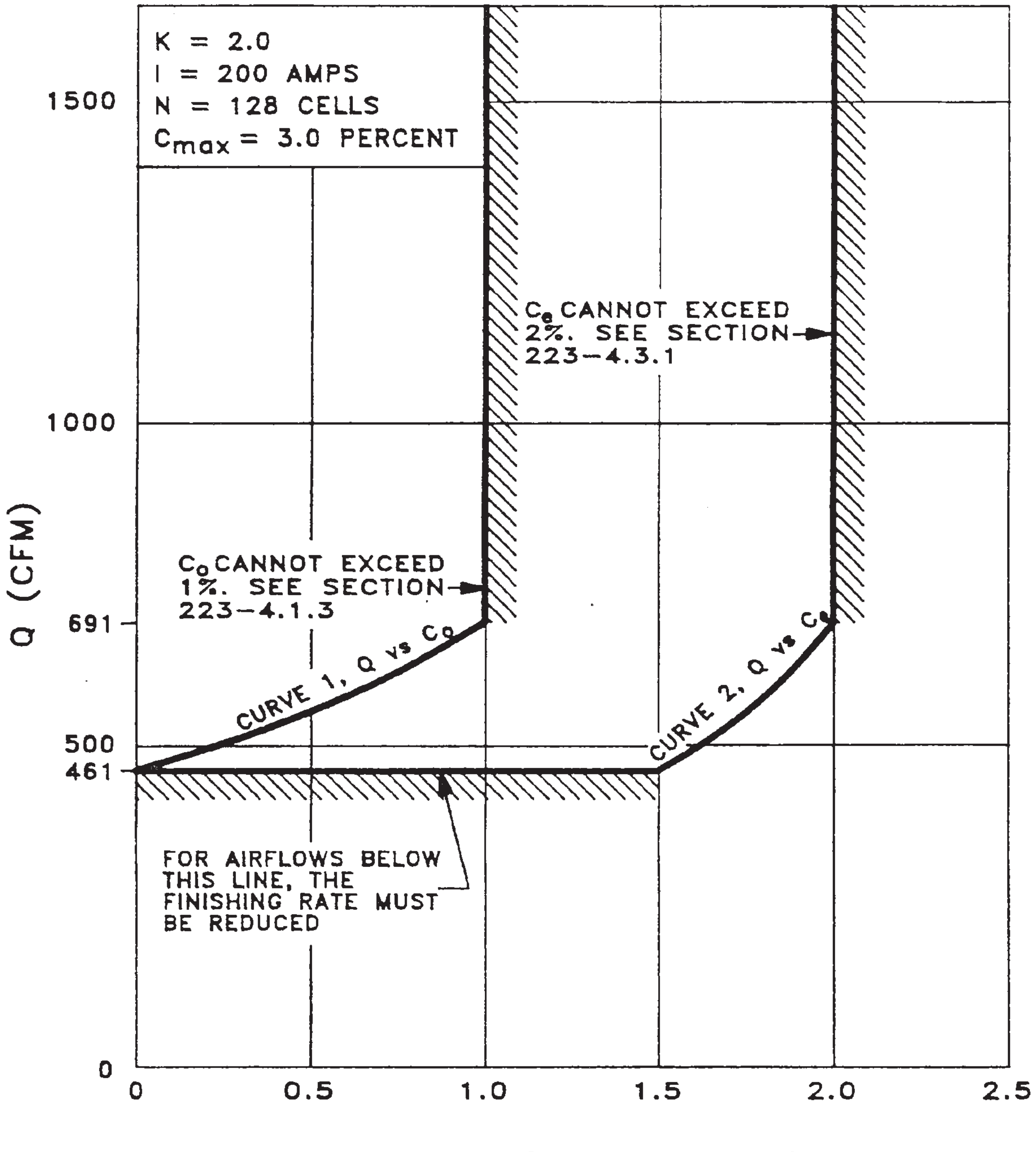


Figure 223−21. Ventilation Airflow Rate vs. C_o or C_e for Surfaced or Submerged Battery Charging (OHIO Class Submarines)

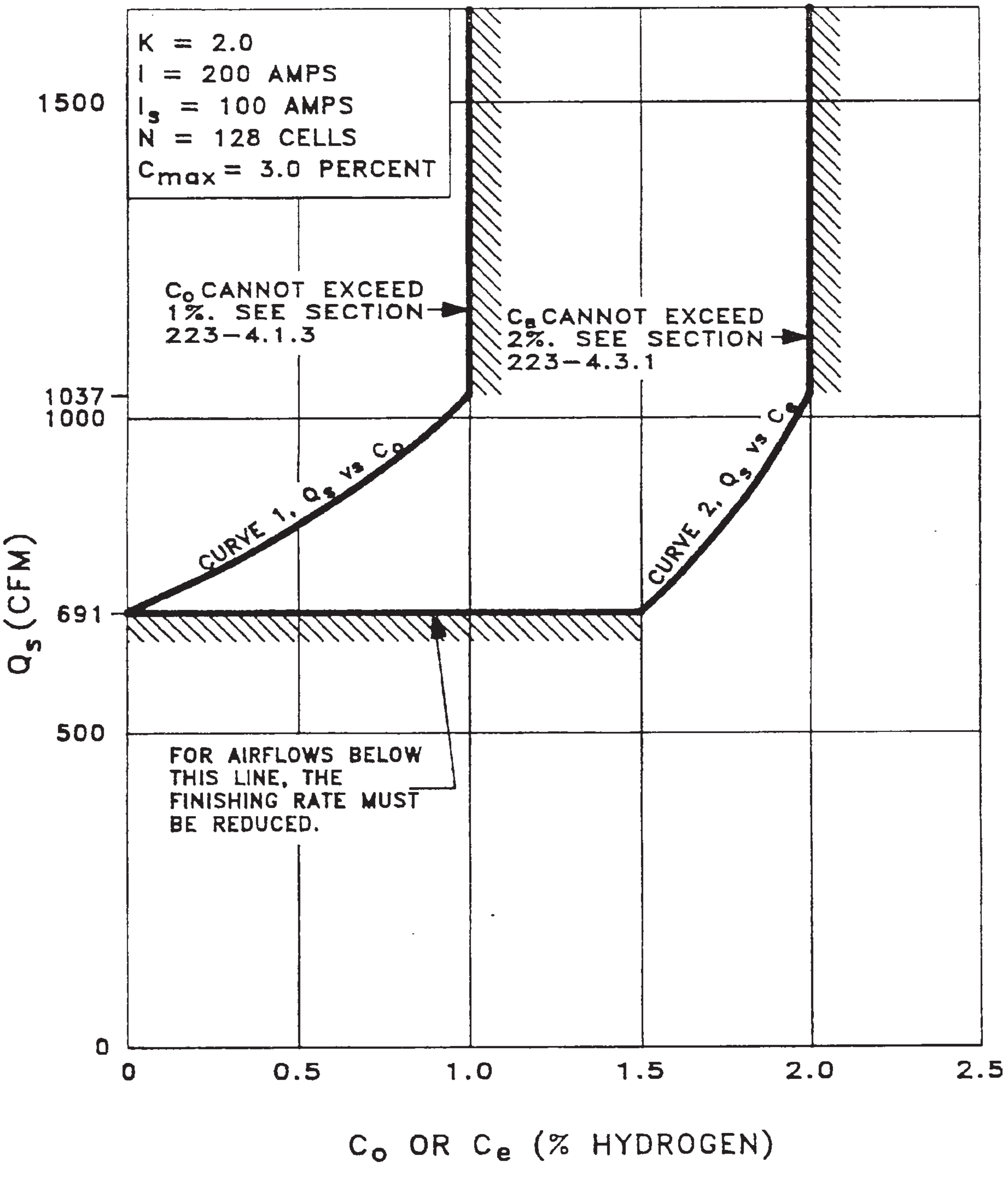


Figure 223−22. Ventilation Airflow Rate vs. C_o or C_e for Battery Charging While Snorkeling (OHIO Class Submarines)

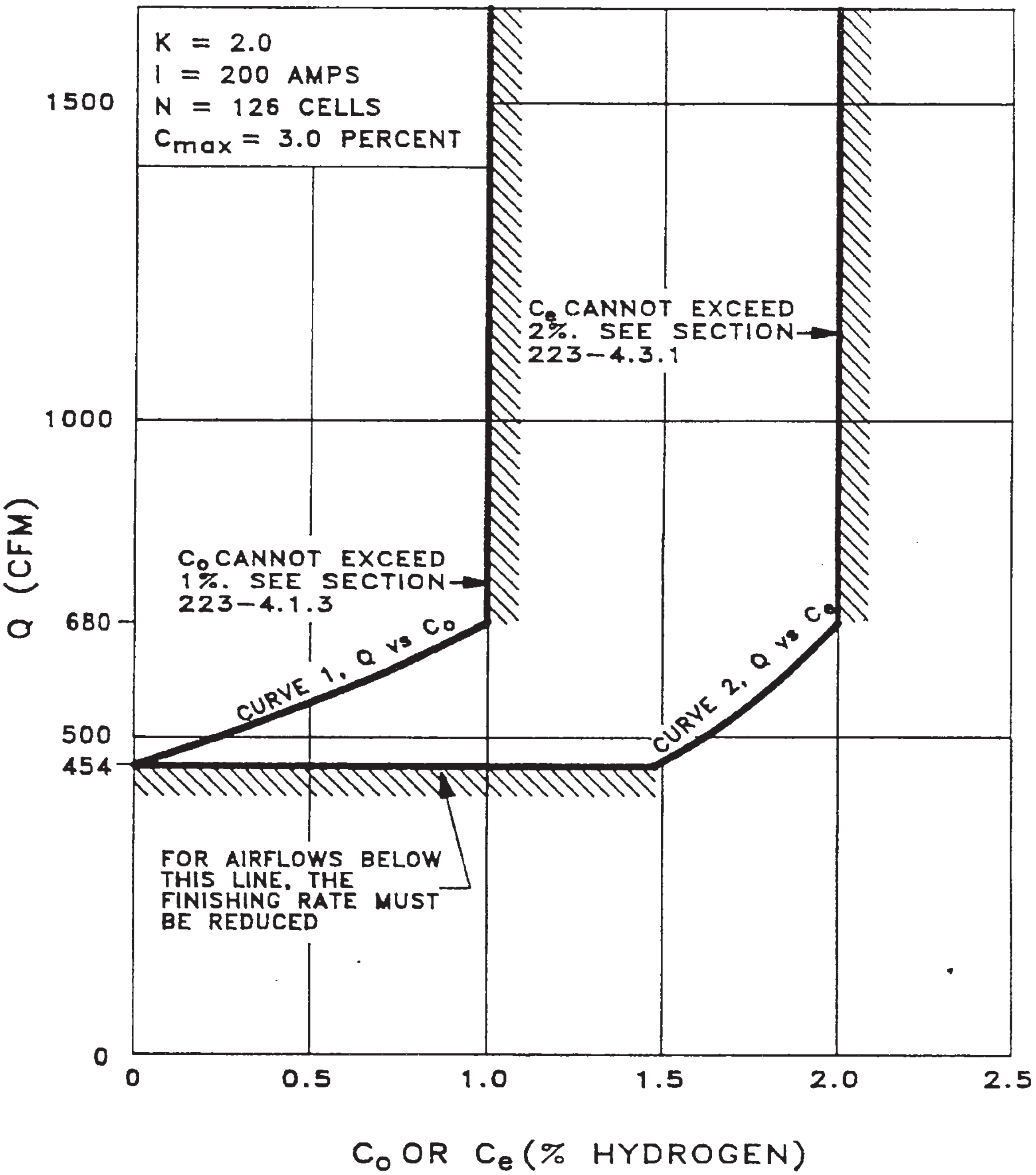


Figure 223−23. Ventilation Airflow Rate vs. C_0 or C_e for Surfaced or Submerged Battery Charging (All Classes with K=2.0, I=200 Amps and N=126 Cells)

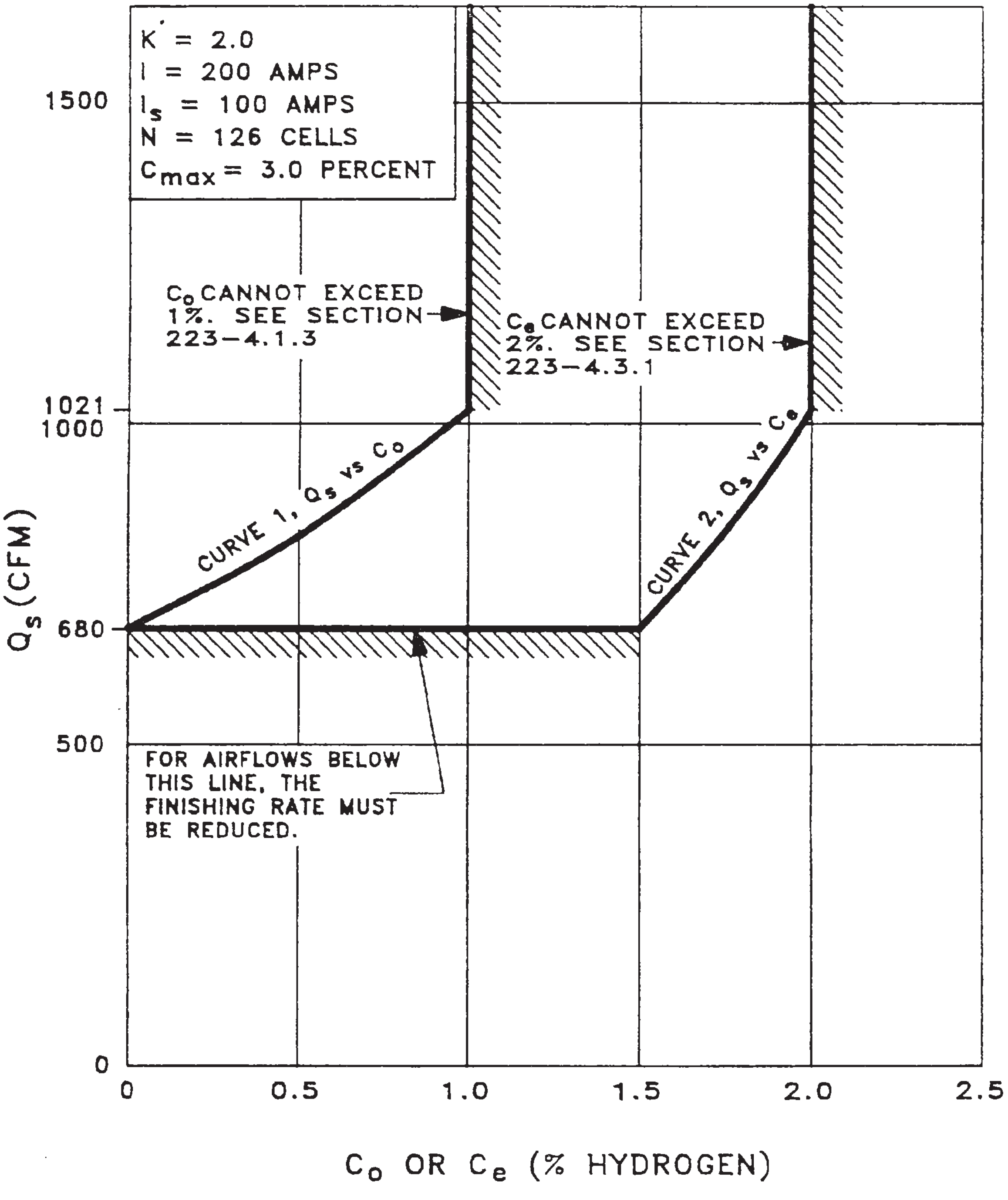


Figure 223−24. Ventilation Airflow Rate vs. C_o or C_e for Battery Charging While Snorkeling (All Classes with K=2.0, I=200 Amps and N=126 Cells)

The $Q_{s,min}$ vs. C_o curve speed is plotted in Figure 223−20 as Curve 1.

The relationship between Q_s and C_e is determined by substituting the known values of I, I_s, N and K into equation (14), as follows:

$$Q_{s,min} = \frac{0.027(I + I_s)(N)(K-1)}{(C_{max} - C_e)}$$

$$= \frac{0.027(200 + 100)(126)(2.5-1)}{(3.0 - C_e)}$$

$$= \frac{1530.9}{(3.0 - C_e)}$$

The Q_s vs. C_e curve is labeled Curve 2 in Figure 223−20.

223−4.3.2.7 Q versus C Curves for OHIO Class Submarines, Surfaced or Submerged Operations. For OHIO Class submarines:

$K = 2.0$

$I = 200$ amperes

$N = 128$ cells

$C_{max} = 3.0$ percent

Using equations (11) and (12), Q vs. C curves, similar to those developed for LOS ANGELES Class submarines, can be developed for OHIO Class submarines.

Figure 223−21 shows these curves for surfaced or submerged operations and the conditions listed above.

223−4.3.2.8 Q versus C Curves for OHIO Class Submarines, Snorkel Operations. A similar set of Q_s vs. C curves can be constructed by substituting the values of K, N, I and I_s peculiar to OHIO Class submarines into equations (13) and (14). Figure 223−22 shows these curves for snorkel operations.

223−4.3.2.9 Q Versus C Curves for Submarine Classes with K=2.0, I=200 Amps, and N=126 Cells, Surfaced or Submerged Operations. For submarine classes with K=2.0, I=200 amps, and N=126 cells, Q vs. C curves can be developed, similar to those for LOS ANGELES and OHIO Class submarines. Figure 223−23 shows these curves for surfaced or submerged operations.

223−4.3.2.10 Q Versus C Curves for Submarine Classes with K=2.0, I=200 Amps, and N=126 Cells, Snorkel Operations. For submarine classes with K=2.0, I=200 amps, and N=126 cells, Q vs. C curves can be developed, similar to those for LOS ANGELES and OHIO Class submarines. Figure 223−24 shows these curves for snorkel operations.

223−4.3.2.11 Ventilation Requirements for a Discharging or Open-circuited Battery. A small amount of hydrogen is released by the ship's battery when it is discharging or on open-circuit. (see sections 223−1.5.3.3 and 223−4.1.2) Since hydrogen is constantly being released by the battery, the battery compartment exhaust system should be operating at all times. Experience has shown that a minimum ventilation rate, Q_d, of two cfm per battery cell should be maintained while the battery is discharging or in the open-circuit mode. Mathematically:

$$Q_d = 2N$$

Where: Q_d = the minimum battery compartment ventilation rate for a battery which is discharging or on open-circuit, in cubic feet per minute (cfm).

Very little hydrogen should be evolved under these conditions. Therefore, if the value of C_e measured by the ship's hydrogen detector climbs above a nominal level, the ventilation rate should be increased and the cause of the increased hydrogen concentration should be determined.

For any charging operation in which the charging rate used is less than the normal finishing rate (e.g., trickle or float charging), the minimum allowable airflow rate is determined by equation (11), equation (13) if snorkeling, or equation (15), whichever is greater. Thus, under no circumstances will the battery compartment ventilation rate ever be less than two cfm per battery cell.

223−4.3.3 BATTERY FINISHING RATE LIMITS

223−4.3.3.1 Calculating the Maximum Battery Finishing Rate for Surfaced or Submerged Operations. If the hydrogen removal/burning capabilities of the $CO\text{-}H_2$ burners or the airflow rate of the ventilation system are reduced such that charging the battery causes C_o or C_e to reach unsafe levels, the ship's battery may have to be charged at a reduced finishing rate. The maximum battery finishing rate, I_{max}, is determined by solving equation (11) for I, using the known value of C_o (or C_e) and Q. For surfaced or submerged operation, the maximum finishing rate, I_{max}, is determined as follows:

a. For surfaced or submerged operations and known values of C_o:

$$I_{max} = \frac{Q(C_{max} - C_o)}{(0.027)(N)(K)} \qquad (16)$$

Where: I_{max}= the maximum allow-allowable battery charging finishing rate, in amperes.

NOTE

> During surfaced operations, if all battery compartment ventilation air is discharged overboard, the ambient hydrogen concentration of the air entering the battery compartment, C_o, should be zero percent.

b. For surfaced or submerged operations and known values of C_e:

$$I_{max} = \frac{Q(C_{max} - C_e)}{(0.027)(N)(K\text{-}1)} \qquad (17)$$

In calculating the value of I_{max}, the actual, measured value of Q should be used. As in previous calculations, C_{max} equals 3.0 percent.

223−4.3.3.2 Calculating the Maximum Battery Finishing Rate for Snorkel Operations. Similarly, if the airflow rate of the ventilation system is reduced during snorkel operations, the ship's battery may have to be charged at a reduced finishing rate. The maximum battery finishing rate, I_{max}, is determined by solving equations (13) and (14) for I, using the known values of C_o (or C_e) and Q_s. It is especially important that the maximum safe finishing rate be known under these conditions since fluctuations in the ambient barometric pressure may affect the accuracy of the ship's hydrogen detectors. Since the accuracy of the battery charging ammeter is not affected by the cycling of the snorkel head valve, it can be utilized to conduct a safe battery charge while snorkeling. The maximum safe finishing rate, I_{max}, for snorkel operations is determined as follows:

a. For snorkel operations and known values of C_o:

$$I_{max,s} = \left[\frac{Q_s(C_{max} - C_o)}{(0.027)(N)(K)}\right] - I_s \qquad (18)$$

b. For snorkel operations and known values of C_e:

$$I_{max,s} = \left[\frac{Q_s(C_{max} - C_e)}{(0.027)(N)(K - 1)}\right] - I_s \qquad (19)$$

In calculating the value of I_{max}, the actual, measured value of Q_s should be used. As in previous calculations, C_{max} equals 3.0 percent and I_s equals 100 amperes per operating diesel engine.

223−4.4 EMERGENCY BATTERY COMPARTMENT VENTILATION PROCEDURES

223−4.4.1 EMERGENCY PROCEDURE FOR AIRFLOW METER FAILURE. Conducting a battery charge with an inoperative airflow meter is considered an emergency procedure. If a venturi-type airflow meter is used to measure airflow and the venturi is damaged, no attempt should be made to charge the battery. If the venturi is not damaged, a U-tube manometer, or magnahelic gage, can be connected to the venturi and the volumetric airflow rate computed with the ship's calibration curves. (see section 223−4.2.2.4) Before the charging operation is started, a continuous watchstation should be established at the manometer. The watchstander should be kept in continuous telephone communication with the battery charging operator.

223−4.4.2 EMERGENCY PROCEDURE FOR HYDROGEN DETECTOR FAILURE. Conducting a battery charge with an inoperative hydrogen detector is considered an emergency procedure. The Central Atmosphere Monitoring System (CAMS) should be utilized to monitor the hydrogen of the ambient air entering the battery compartment, C_o, at 20-minute intervals. The CAMS should also be used to continuously monitor the hydrogen concentration of the battery compartment exhaust air, C_e. Continuous telephone communication should be established between the CAMS operator and maneuvering.

223−4.4.3 ESTABLISHING BATTERY COMPARTMENT VENTILATION AFTER AN INTERRUPTION IN AIRFLOW. Caution should be taken to eliminate sparking or other possible sources of ignition when re-establishing battery compartment ventilation after an interruption or after the battery compartment has been sealed for an extended period of time. The hydrogen evolved during the ventilation stoppage will, in all probability, have accumulated in the cell tops, the high points in the compartment, and in the ventilation ductwork. Therefore, the potential for an explosion increases in direct proportion to the length of time that the battery compartment has been unventilated. Extreme caution should be exercised when ventilation fans or other electrical devices are energized. In such situations, the following precautions should be observed:

a. Do not operate the battery breakers or any electrical equipment in the battery compartment.

b. Shut the battery compartment ventilation isolation valves.

c. Draw air samples from the battery compartment through sample ports, if provided. Samples should be analyzed with the CAMS or Draeger tubes to determine the hydrogen concentration within the compartment.

d. Align the fan room exhaust fan, low-pressure blower or diesel to draw ventilation air from spaces other than the battery compartment. When full airflow has been established, the battery compartment isolation valves (on both the intake and exhaust sides of the compartment) should be opened slightly to draw hydrogen-rich air from the battery compartment at a very low rate. By drawing a small amount of hydrogen-rich air from the battery compartment and mixing that air with a large amount of hydrogen-free air from another compartment, the hydrogen in the battery compartment air is diluted to a nonexplosive concentration before it reaches the fan room exhaust fan, low pressure blower or diesel. Once the hydrogen concentration in the battery compartment exhaust duct, C_e, has dropped to 1.5 percent, the battery compartment isolation valves can be opened slightly further. This procedure should be continued until the isolation valves are fully open. Full ventilation should be maintained for no less than 20 minutes after the hydrogen concentration in the battery compartment exhaust duct has dropped to zero percent.

223−4.5 TEMPORARY BATTERY COMPARTMENT VENTILATION

Until the entire ventilation system has been installed, balanced and tested, the battery compartment exhaust system should be considered a temporary ventilation system. Temporary ventilation systems can be classified as either overboard or inboard discharge type systems. Both types of temporary ventilation systems are permitted during construction or overhaul work.

223−4.5.1 OVERBOARD DISCHARGE TEMPORARY VENTILATION SYSTEMS. An overboard discharge temporary ventilation system is one which exhausts all of the hydrogen-rich battery compartment ventilation air directly overboard. The ship’s diesel (or low-pressure blower) can be used to ventilate the battery compartment if it (i.e., the diesel or low-pressure blower) and its associated ductwork (from the battery compartment to overboard) are installed and operational. If the air movers are not available, externally-mounted (dockside) temporary ventilation fans can be used to ventilate the battery compartment. Externally-mounted temporary ventilation fans should be connected to the battery compartment exhaust plenum or exhaust ductwork by temporary, flexible ductwork. The discharge openings from temporary ventilation systems should be located away from all potential ignition sources. Hot work is prohibited within 25 feet of discharge openings. In addition, discharge openings should be located where discharged hydrogen cannot be recirculated to the ship’s interior. As long as a primary air mover and a back-up air mover are provided, any combination of externally-mounted fans, the ship’s diesel or the low-pressure blower can be used in an overboard discharge temporary ventilation system. To ensure that battery compartment ventilation can be provided at all times, both air movers should be capable of providing the minimum, safe battery compartment ventilation rate for charging. In addition, both air movers should be powered from different power sources.

223−4.5.2 INBOARD DISCHARGE TEMPORARY VENTILATION SYSTEMS. An inboard discharge temporary ventilation system is one which exhausts all of the hydrogen-rich battery compartment ventilation air inboard. This type of temporary ventilation system requires that at least 1500 cfm of hydrogen-free ventilation air be drawn into the forward section of the ship (which contains the battery compartment) and mixed with the battery compartment exhaust. The low-pressure blower, the diesel engine, the main induction system or an externally-mounted temporary ventilation fan can be used to provide the required ventilation air. At least one forward hatch must be left open to allow ventilation air to enter or leave the hull. In addition to the system providing weather air, a battery compartment ventilation system (including the battery ventilation fans, the air distribution plenums, all associated ductwork, the airflow meter and the hydrogen detector) must be installed and operational. The battery ventilation fans must be capable of ventilating the battery compartment at the required minimum ventilation rate for battery charging. Finally, to ensure that the hydrogen-rich air exhausted from the battery compartment is thoroughly mixed with the 1500 cfm of weather air drawn into the ship, it is required that the forward ventilation system be functioning. It is not a requirement that the system be completed or balanced, but at least half of the forward compartment ductwork should be installed.

223−4.5.3 PREPARING TEMPORARY VENTILATION SYSTEMS FOR BATTERY CHARGING. The following procedures should be adhered to when preparing for conducting a battery charge with a temporary ventilation system (regardless of type):

1. The Supervisor of Shipbuilding, Conversion and Repair, U. S. Navy (SUPSHIP), the construction activity and the overhaul activity are responsible for designating Battery Charging Coordinators responsible for certifying that temporary services are complete and conditions are satisfactory for safely charging the battery during construction and overhaul.

2. Calculate the minimum safe battery compartment ventilation rate for charging, Q, using equation (11) as follows:

$$Q = \frac{0.027(I)(N)(K)}{(C_{max} - C_o)}$$

Where: C_{max} = 3.0 percent

C_o = 0.0 percent for an overboard discharge temporary ventilation system.

C_o = 1.0 for an inboard discharge temporary ventilation system.

3. Inspect the temporary ventilation system − including the inlet plenum, the exhaust plenum, the selected air movers (both primary and back-up), all ductwork (both temporary and permanent), the airflow meter and the hydrogen detector. If the ship's permanent hydrogen detector is not being used, two temporary hydrogen detectors must be installed in the temporary ventilation system. All equipment to be used during the charging operation should be properly aligned and fully operational. Clean filters (either temporary or permanent) should be installed in the supply air intake.

4. Establish watch stations at the hydrogen detector and airflow meter indicators (if remote indicators are not located at the battery charging control point). All watchstanders should be in continuous telephone communication with maneuvering.

WARNING

If for any reason personnel must enter the battery compartment, the battery charging operation should be secured. Full ventilation should be maintained for a period of no less than 20 minutes before any access to the compartment is attempted. Full ventilation should continue while personnel are in the compartment. The charging operation should not be resumed until all personnel are out of the compartment and the access hatch has been closed.

WARNING

If the temporary ventilation system fails or stops for any reason during the charging operation, THE CHARGING OPERATION SHOULD BE SECURED IMMEDIATELY.

223−4.5.4 TEMPORARY VENTILATION REQUIREMENTS FOR BATTERY CHARGING − OVERBOARD DISCHARGE SYSTEMS. Once the preparations described in the previous section have been made, the battery charging operation can be started. The following procedures should be adhered to when conducting a battery charge with an overboard discharge temporary ventilation system:

1. Check the temporary ventilation system fans to verify that they are rotating in the proper direction, operating at full speed and providing the required minimum ventilation. Once the minimum ventilation rate has been verified, the system should be allowed to stabilize for a period of at least 20 minutes.

2. Alert all personnel to be on the watch for the inadvertent misalignment of battery compartment ventilation system closures, bulkhead doors, valves, weather hatches, natural supply inlets and battery access hatches.

3. Monitor the airflow through the battery compartment and the hydrogen concentration in the battery compartment exhaust ductwork, C_e, throughout the charging operation to ensure that the temporary ventilation system is providing the required minimum ventilation.

4. Operate the battery ventilation system (at its maximum rate) for at least 20 minutes after the battery charging operation has been secured.

223−4.5.5 TEMPORARY VENTILATION REQUIREMENTS FOR BATTERY CHARGING − INBOARD DISCHARGE SYSTEMS. Once the preparations described in section 223−4.5.3 have been made, the battery charging operation can be started. The following procedures should be adhered to when conducting a battery charge with an inboard discharge temporary ventilation system:

1. Isolate the after compartment(s) from the forward compartment by closing all doors, hatches, valves, dampers and other openings between the two areas. By isolating the after compartment(s) of the ship from the forward compartment, hot work can proceed in the after compartment(s) while the battery charge is being performed in the forward compartment. Hot work is prohibited in the forward compartment and within 25 feet of open top-side hatches during battery charging.

2. Check all the temporary ventilation system fans to verify that they are rotating in the proper direction, operating at full speed and are providing the required minimum ventilation. Once the minimum ventilation rate has been verified, the system should be allowed to stabilize for a period of at least 20 minutes.

3. Ensure that the fan room is operating under a slight negative pressure if it is being used to dilute the battery compartment exhaust. On systems of this type, the fan room door should be left open at all times to prevent a reduction in battery airflow or, in the event of a battery fan failure, to ensure adequate residual battery airflow.

4. Alert all personnel to be on the watch for the inadvertent misalignment of battery compartment ventilation system closures, bulkhead doors, valves, weather hatches, natural supply inlets and battery access hatches.

5. Monitor the airflow through the battery compartment and the hydrogen concentration in the battery compartment exhaust ductwork, C_e, throughout listed in Table 223–14 (at a minimum) the charging operation to ensure that the temporary ventilation system is providing the required minimum ventilation.

6. Monitor the hydrogen concentration at the locations listed in Table 223–14 (at a minimum) throughout the charging operation. Portable hydrogen monitoring equipment should be used to ensure that the specified safe concentration limits given in Table 223–14 are not exceeded.

7. Operate the battery ventilation system (at its maximum rate) for at least 20 minutes after the battery charging operation has been secured.

Table 223–14. HYDROGEN CONCENTRATION LIMITS FOR BATTERY CHARGING WITH TEMPORARY VENTILATION

Monitoring Location	Maximum hydrogen concentration
Battery compartment intake duct	1.0 percent
Battery compartment exhaust duct	1.5 percent 1.2 percent*
Battery compartment forward, port, overhead	3.0 percent
Battery compartment aft, port, overhead	3.0 percent
Battery compartment forward, stbd. overhead	3.0 percent
Battery compartment forward, aft. stbd. overhead	3.0 percent
Operations compartment (several locations)	1.0 percent
*Los Angeles Class Submarines.	

223–4.5.6 TEMPORARY VENTILATION REQUIREMENTS FOR A DISCHARGING OR OPEN-CIRCUITED BATTERY. A temporary battery ventilation system can also be used to maintain a safe hydrogen concentration in the battery compartment while the ship's battery is discharging or in the open-circuit mode. The following procedures should be adhered to when the battery is discharging or open-circuited:

1. Before the battery is connected to an operating electrical circuit or placed in the open-circuit mode, the battery ventilation rate and the hydrogen concentration in the

exhaust ductwork, C_e, should be checked. The airflow rate must be at least two cfm per battery cell. (see equation (15) in section 223−4.3.2.11) The hydrogen concentration in the exhaust ductwork must be nominal.

2. Two air movers, each capable of delivering the minimum airflow, must be available to the temporary ventilation system. Only one needs to be operated continuously; the second is to be held in standby in case the primary fails.

3. While the battery compartment is being ventilated by a temporary ventilation system, personnel should be alert for the inadvertent misalignment of closures, bulkhead doors, valves, weather hatches, natural supply inlets and battery access hatches.

4. While the battery compartment is being ventilated by a temporary ventilation system, a roving watchstander should verify, on an hourly basis, that the temporary battery compartment ventilation system is operational. A streamer tied to the ventilation system's discharge opening should be sufficient for this purpose. If the ship's battery is discharging (i.e., not in the open-circuit mode), the roving watchstander should also monitor the hydrogen concentration in the battery compartment exhaust stream on an hourly basis. The ship's hydrogen detector, the Central Atmosphere Monitoring System (CAMS) or a portable hydrogen detector should be used for this purpose.

223−4.6 BATTERY COMPARTMENT EXHAUST SYSTEM TESTING

223−4.6.1 BATTERY COMPARTMENT EXHAUST SYSTEM TESTS. Battery compartment exhaust system testing may include any or all of the following tests:

a. Battery Compartment Exhaust System Airflow Rate Test. This test is conducted to determine the battery compartment exhaust system airflow rate. Accomplishment of this test is required during new construction, overhaul, and whenever components of the battery compartment exhaust system are overhauled or modified. (see section 223−4.6.5)

b. Battery Compartment Airflow Distribution Test. This test is conducted to determine the effectiveness of the battery compartment supply and exhaust plenums in maintaining an even distribution of ventilation air across the battery compartment. (see section 223−4.6.6)

c. Battery Compartment Ventilation System K-Factor Test. This test is conducted to determine the actual value of the hydrogen distribution factor, K, for the installed battery compartment exhaust system. (see section 223−4.6.7)

d. Battery Compartment Ventilation System I_s Test. This test is conducted to determine the actual value of the equivalent charging rate, I_s, for the installed battery compartment exhaust system. (see section 223−4.6.8)

These tests provide the basis for evaluation of the operational capabilities of the battery compartment exhaust system.

223−4.6.2 BATTERY COMPARTMENT VENTILATION SYSTEM TEST PERSONNEL.

223−4.6.2.1 Battery Compartment Exhaust System Test Coordinators. Submarine construction and overhaul activities should designate battery compartment exhaust system test coordinators. Coordinators should have extensive backgrounds in battery charging operations and in the design, operation and testing of battery compartment exhaust systems. The duties of the battery compartment exhaust system test coordinators are as follows:

Test coordinators are responsible for:

a. Familiarizing themselves with the design and test requirements of the ship being tested.

b. Training personnel participating in battery compartment exhaust system tests.

c. Supervising the design, installation and preparation of all temporary ventilation or instrumentation systems required for testing.

d. Ensuring that the battery compartment ventilation and instrumentation systems being used for the tests (whether temporary or permanent) are ready for testing.

e. Determining the minimum ventilation airflow rates required for the tests; and for verifying that the ventilation system being used for each test is providing the required minimum ventilation.

f. Preparing the battery compartment exhaust system test plan in accordance with section 223−4.6.4.

g. Supervising the testing and preparing the final, written test report.

h. The safety of the ship and all test personnel. They should be thoroughly versed in all aspects of battery charging and battery compartment exhaust system testing safety.

i. Maintaining control of all charging operations and all test procedures. They are responsible for and have the authority to stop or postpone any charge or test at any time.

223−4.6.2.2 Battery Compartment Ventilation Project Engineer. SUPSHIP has cognizance of submarine construction and, therefore, responsibility for inspecting the completed battery compartment exhaust system. SUPSHIP is responsible for designating a battery compartment ventilation project engineer who is responsible for maintaining a set of safe, effective, testing and inspection procedures. SUPSHIP is responsible for issuing those procedures to private submarine construction and overhaul activities for their use. In addition, SUPSHIP is responsible for ensuring that the procedures outlined in those instructions are implemented.

223−4.6.3 BATTERY COMPARTMENT EXHAUST SYSTEM TEST EQUIPMENT. The construction or overhaul activity conducting the battery compartment ventilation system testing is also responsible for providing all temporary instrumentation, equipment, tools and facilities required for the tests.

223−4.6.4 BATTERY COMPARTMENT EXHAUST SYSTEM TEST PLAN. A complete battery compartment exhaust system test plan should be prepared by the test coordinators. The test plan should identify tests to be performed, when those tests are to be performed, the order in which they are to be performed, the equipment required, the responsibilities of all activities taking part in the tests and all test procedures. The following guidelines should be adhered to when developing the battery compartment exhaust system test plan:

a. Tests should be performed under conditions as close to the ship's normal operating conditions as possible.

b. Tests should not be conducted until the installation and calibration of the hydrogen detectors and airflow meters being used for the tests (both temporary and permanent) have been completed.

c. Tests should not be performed until the installation of all features, devices and equipment items affecting the airflow distribution within the battery compartment (i.e., walking flats, ion exchangers, electrolyte agitation system, water-cooling system and similar items) have been completed.

d. Tests should be scheduled to minimize the amount of time that the battery is being charged. Otherwise, a substantial portion of battery life will be used on test work alone.

e. Tests should not be conducted until the responsible construction or overhaul activity has thoroughly inspected the battery compartment exhaust system for completeness. Ductwork should be visually inspected for tightness. Connections (both wiring and piping) to the airflow meter and hydrogen detector should be inspected. The system fans should be checked to ensure they are properly installed and rotating in the proper direction. If necessary, system instrumentation should be recalibrated. If temporary ventilation is to be used for the tests, all temporary equipment, ductwork and instrumentation should be inspected for completeness.

223−4.6.5 BATTERY COMPARTMENT EXHAUST SYSTEM AIRFLOW RATE TEST. This test is conducted to determine the airflow rate, Q, through the battery compartment. Airflow rate tests may need to be performed on both temporary and permanently installed battery compartment ventilation systems. Further, airflow rate tests may be required for several different system alignments and operating modes. An airflow rate test should be performed after any of the following events:

a. Upon completion of the installation of a new battery compartment ventilation system.

b. Upon completion of any overhaul or repair work performed on an existing battery compartment ventilation system − including all fans, dampers, valves, ductwork, supply/exhaust plenums, etc. − if that work changes the configuration of the installed system.

c. Upon completion of the installation or removal of a temporary, in-port battery compartment ventilation system.

223−4.6.5.1 Measuring the Battery Compartment Ventilation Rate. Once the conditions for a ventilation rate test of a particular system alignment have been set, the ventilation system should be allowed to stabilize for at least 20 minutes. A similar stabilization period should be provided between test runs. The volumetric airflow rate should be measured with both a test instrument (in accordance with ASHRAE Standard 41.7−84, “Method for Measurement of Flow of Gas,”) and the ship’s airflow meter. If the difference between the two airflow rates is greater than 10.0 percent, the system airflow rate should be re-measured and the calibration of the ship’s airflow meter should be verified. For the permanent battery compartment ventilation system, volumetric airflow rates should be determined for all anticipated system alignments and conditions, including emergency ventilating conditions.

223−4.6.6 BATTERY COMPARTMENT AIRFLOW DISTRIBUTION TEST. This test is conducted to determine the effectiveness of the battery compartment supply and exhaust plenums in maintaining an even distribution of ventilation air across the battery compartment. An airflow distribution test should be conducted after any of the following events:

a. Installation or modification of the supply or exhaust plenums.

b. Repair of the supply or exhaust plenums when it is not possible to visually inspect the repaired area in its entirety, to verify the configuration of the plenum has not been altered.

c. Modification of the supply or exhaust ductwork within 7-1/2 duct diameters of the plenums.

223−4.6.6.1 Conducting a Battery Compartment Airflow Distribution Test. The procedure for conducting a battery compartment airflow distribution test is as follows:

1. Verify all of the ship's battery compartment exhaust system ductwork and components are installed for a minimum distance of 7-1/2 duct diameters from the supply and exhaust plenums, to ensure the measured airflow distribution is not altered by temporary ventilation.

2. Ventilate the battery compartment at the design flow rate within design specifications.

3. Survey the battery compartment airflow distribution by measuring the velocity of the air exiting the supply plenum slots and entering the exhaust plenum slots with a hot-wire anemometer. The equal area traversing method should be applied by dividing the cross-sectional area into a minimum of nine equal areas and traversing the center of each area. Traverse points should be approximately two to 2-1/2 inches apart, but no greater than three inches. Measurement points should be held constant within one to two inches in front of the slot.

4. Verify that the plenum slot airflow distribution is in accordance with design specifications. If not, the slots should be adjusted and the test repeated until requirements are met.

223−4.6.7 BATTERY COMPARTMENT EXHAUST SYSTEM K-FACTOR TEST. This test is conducted to determine the actual value of K for a particular battery compartment exhaust system configuration. To do this, the hydrogen concentration is measured at a minimum of 40 points within the battery compartment and compared with the hydrogen concentration measured in the battery exhaust duct. The K-factor, by definition, is the ratio of the highest concentration in the compartment to the concentration in the exhaust duct. A battery compartment exhaust system K-factor test should be conducted after any of the following events:

a. Installation or modification of the supply or exhaust plenums. A K-factor test is not required if three ships of the same class with identical battery compartment plenums and battery compartment exhaust system configurations have satisfactorily completed K-factor tests.

b. Whenever a major equipment item is removed, installed or relocated in the battery compartment.

c. Whenever the K-factor is in doubt.

The battery compartment airflow distribution test must be completed prior to conducting the K-factor distribution test.

223−4.6.7.1 Locating Sampling Points for a K-factor Test. To ensure that the hydrogen concentration measurements taken during the K-factor test are as indicative of the actual conditions within the battery compartment as possible, a minimum of 40 sampling points should be used. This will ensure that the effect of a localized hydrogen source, such as the vent of one particular battery cell, will be minimized. Sampling points should be located as follows:

a. A sampling point should be located in (or adjacent to) the battery compartment ventilation system supply air inlet.

b. A sampling point should be located in the battery compartment ventilation system exhaust duct near the ship's hydrogen detector sensing unit. Since the hydrogen concentration at this point is used to determine the values of K and I_s, the sample taken at this point is used to verify the calibration of the ship's permanently installed hydrogen detector.

c. One or two sampling points should be located below each walking flat. These sampling points should be located between two battery cells, not directly over a single cell.

d. A sampling point should be located at any location suspected of having a low airflow rate. This (low-flow) condition may be due to the geometry of the battery compartment, the layout of the ventilation plenums or the location of equipment within the compartment.

e. A sampling point should be located near each corner of the exhaust side of the battery compartment.

f. The remaining sampling points should be distributed randomly throughout the battery compartment. In general, they should be located near the overhead. However, at least one sampling point should be located at a low elevation and one at an intermediate elevation within the battery compartment. Since the concentration of hydrogen in the ventilation air should be highest near the exhaust plenum, an emphasis should be placed on locating sampling points in that area.

223−4.6.7.2 Preparing A Sampling Point Map. A sampling point map should be prepared showing the proposed locations of all sampling tubes within the battery compartment. The map should be a plan view of the compartment, oriented with forward at the top of the sheet. The ship's coordinate system, the location and arrangement of the access hatch, all structural members, all equipment items within the compartment and all other features having some bearing on the airflow pattern should be clearly indicated on the map. The location of each ventilation system inlet and outlet opening should be shown and the coordinates of the extremities of each opening clearly marked. The coordinates of each sampling point, including elevation, as well as any other required descriptive or explanatory notes, should also be included on the map. The battery cells should be used to define a basic grid for identifying the sampling points.

223−4.6.7.3 Installing Sampling Tubes. Sampling tubes should be installed according to the following procedure:

1. A removable plate of approximately six inches in diameter is fitted to the deck above the battery compartment. This plate should be replaced with a temporary plate fabricated of plywood or, preferably, plastic. See Naval Sea Systems Command (NAVSEA) Dwg. SS−S6504−985720. The temporary plate should have an opening cut into it just large enough for the sampling tubes to pass through. Since minor leakage through the plate will not seriously impair the test results, it will not be necessary to provide a gasket or sealant around the plate or the tubing.

2. Sampling tubes should be cut from 1/8-inch ID (inside diameter) plastic tubing and should be clearly marked at both ends (at the end to be located at the sampling point in the compartment and at the end which will be attached to the portable test instrument). The tubes should be marked with the numerals 1 through 40. This will greatly facilitate the setting up, conducting, reporting and evaluation of each test. It will also reduce the chance for errors in future reports or correspondence concerning

the tests. The sampling tubes should be passed through the opening in the temporary plate described above. Sufficient tubing length should be provided outside the battery compartment for the tubing to be connected to the portable test instrument. Sufficient tubing length should be provided inside the compartment for the tubing to be located at any sampling point.

3. Locate one end of each sampling tube within the compartment at the sampling points identified on the sampling point map developed in section 223−4.6.7.2, above. If more than one portable test instrument is to be used, at least one sampling tube from each instrument should be located at the sampling point in the battery compartment exhaust duct.

4. Connect the other end of each sampling tube to the correspondingly numbered selector valve on the portable test instrument.

5. Update the sampling point map to reflect the actual locations of the installed sampling tubes.

223−4.6.7.4 Conducting a K-Factor Distribution Test. The procedure for conducting a battery compartment exhaust system K-factor test is as follows:

1. Conduct a battery charge with the battery compartment exhaust system aligned to ventilate the battery compartment overboard to prevent hydrogen from being recirculated to the battery compartment. The battery compartment should be ventilated at the design airflow rate within design specifications. Temporary ventilation can be used provided the ship's ventilation ductwork and components are installed for a minimum distance of 7-1/2 duct diameters from the supply and exhaust plenums.

2. Record the airflow rate and the hydrogen concentration in the battery exhaust duct and calculate the hydrogen generation rate using equation (1). Compare the measured hydrogen generation rate with the theoretical hydrogen generation rate. Continue the battery charge at the finishing rate until one of the following conditions are met:

a. The measured hydrogen generation rate is within 10 percent of the theoretical value.

b. The hydrogen concentration in the battery exhaust duct remains unchanged for a period of one hour.

3. Record the hydrogen concentration reading for each sampling point location. Also record the readings of the ship's hydrogen detector and airflow meter. Repeat the readings. While continuing the battery charge at the finishing rate, reduce the airflow rate in approximately 300-cfm increments and record the hydrogen levels. Two sets of readings should be taken at each airflow rate. Stop the test when any of the hydrogen concentration measurements exceed three percent or when the airflow rate has been reduced to the minimum allowable airflow rate, equation (11), and the hydrogen levels have been recorded.

4. Upon completion of the test, secure the battery charge and increase the ventilation rate to the design airflow rate. Continue to ventilate at this rate for a minimum of 20 minutes.

5. Recirculated hydrogen, C_o, is not permitted while conducting the battery compartment K-factor distribution test.

6. The K-factor should be calculated for each data set by dividing the highest hydrogen concentration reading measured at any sampling point in the battery compartment, C_h, by the hydrogen concentration in the exhaust duct, C_e measured by the same test instrument. The K-factor should not exceed 2.0.

223−4.6.8 BATTERY COMPARTMENT EXHAUST SYSTEM I_S TEST. This test is conducted to determine the actual value of the equivalent charging rate, I_s. A battery compartment ventilation system I_s test should be conducted on the first ship of every class. The I_s test should always be preceded by a K-factor test.

223−4.6.8.1 Conducting an I_s Test. The procedure for conducting a battery compartment ventilation system I_s test is as follows:

1. Charge the battery with the ventilation system lined up in the snorkel mode. All hatches and openings in the ship's hull should be sealed. The diesel engine vacuum cutouts should be set to operate at an equivalent altitude of 7000 feet (approximately seven inches of mercury).

NOTE

> The diesel engine vacuum cutouts should be reset to their normal operational settings upon completion of the I_s test.

2. Measure the battery compartment ventilation rate, Q_s, and the hydrogen concentration in the battery compartment exhaust duct, C_o, with the ship's instrumentation. Measure the hydrogen concentration at the air inlet to the battery compartment, C_o, and in the exhaust duct, C_e, with the portable test instrument. Compare the measured hydrogen generation rate with the theoretical hydrogen generation rate.

3. Continue the battery charge at the finishing rate until one of the following conditions are met:

   a. The measured hydrogen rate is within 10 percent of the theoretical value.

   b. The hydrogen concentration in the battery exhaust duct remains unchanged for a period of one hour.

4. The snorkel head valve should be shut so that the ambient pressure within the ship drops to an equivalent altitude of approximately 6500 feet (as indicated on the ship's altimeter). The head valve should be cycled, as necessary, to maintain this ambient pressure throughout the test run. The hydrogen concentration in the battery exhaust duct, C_e, should be measured with the portable test instrument and with the ship's hydrogen detector at 15-second intervals. Continue to measure C_e until the maximum concentration is attained.

5. Open the head valve and secure the battery charge. Continue to ventilate the battery compartment at the maximum rate for a period of not less than 20 minutes.

WARNING

> During the I_s test, the hydrogen concentration in the exhaust duct, C_e, should not be allowed to exceed 1.5 percent. If this limit is reached, the battery charge should be secured and the head valve opened.

6. Compute the value of I_s by multiplying the actual battery charging rate by the ratio of the increase in the hydrogen concentration due to the closing of the head valve to the normal concentration in the exhaust duct (head valve open).

223−4.6.9 BATTERY COMPARTMENT EXHAUST SYSTEM TEST REPORT.

223−4.6.9.1 Preparing the Test Summary Report. A written report should be prepared summarizing the following information:

a. The calculated value of K

b. The calculated value of I_s

c. A statement certifying that the ship's hydrogen detector and airflow meter are calibrated properly operating in a manner consistent with the test data

d. A brief summary of any and all discrepancies noted, their probable causes and possible solutions. Any temporary repairs shall be pointed out and recommendations for their permanent solutions shall be made

e. The report should also include a statement of the approximate maximum battery compartment ventilation rate obtainable for each operating mode. The report should also include a statement as to whether the available battery compartment ventilation rate is sufficient for charging at the prescribed finishing rate, including snorkel charging when applicable. If the maximum battery compartment ventilation rate is not sufficient for safe operation, the maximum permissible finishing rate, I_{max}, should be stated.

f. The report should include a set of operating guidelines stating the maximum attainable airflow rate for each operating mode the minimum permissable airflow rate for each operating mode and the maximum permissable hydrogen detector readings for each operating mode.

VARIABLES DEFINED IN Section 4.

C_e = the hydrogen concentration of the air in the battery compartment exhaust ductwork, in percent

C_g = the increase in the average hydrogen concentration of the battery compartment ventilation air due to hydrogen generated by the ship's battery (i.e., the concentration increase across the battery compartment), in percent

C_h = The highest measured hydrogen concentration in the battery compartment, in percent. For safety, C_h cannot exceed 3.0 percent. (see section 223−4.1.3)

C_{max} = the maximum allowable hydrogen concentration at any point within the battery compartment, in percent. For safety, C_{max} cannot exceed 3.0 percent

C_o = the hydrogen concentration at the inlet of the battery compartment, in percent

e = the base of the natural logarithims

H = the theoretical hydrogen generation rate, in cubic feet per minute (cfm)

H_s = the theoretical hydrogen generation rate while snorkeling, in cubic feet per minute (cfm)

K = the battery finishing rate, in amperes

I_{max} = the maximum allowable battery finishing rate when submerged or surfaced, in amperes

$I_{max,s}$ = the maximum allowable battery charging finishing rate when snorkeling, in amperes

I_s = the equivalent battery charging rate (i.e., that finishing rate which causes the battery to generate hydrogen at the same rate as the barometric pressure reduction experienced during snorkel operations), in amperes. For calculations, I_s is assigned a valve of 100 amperes per running diesel engine

K = the hydrogen distribution factor

ln = natural logarithm

N = the number of cells in the battery

N_b = the number of operating CO−H_2 burners

Q = the battery compartment ventilation rate, in cubic feet per minute (cfm)

Q_b = the airflow rate through each CO-H_2 burner, in cubic feet per minute (cfm)

Q_d = the minimum airflow rate required to ventilate the battery compartment while the battery is discharging or on open-circuit, in cubic feet per minute (cfm)

Q_{min} = the minimum required compartment ventilation rate while battery charging when submerged or surfaced, in cubic feet per minute (cfm)

$Q_{s,min}$ = the minimum required battery compartment ventilation rate while battery charging when snorkeling, in cubic feet per minute (cfm)

R = the effective battery ventilation rate, in cubic feet per minute (cfm)

t = time, in minutes

V = the ship's floodable volume, excluding the reactor compartment and access and escape trunks, in cubic feet

η_b = the efficiency, of the installed CO-H_2 burners, in percent. Unless otherwise specified, η_b = 90 percent.

SECTION 5.
MAINTENANCE

223−5.1 GENERAL MAINTENANCE PROCEDURE

223−5.1.1 PLANNED MAINTENANCE SYSTEM. Use the Planned Maintenance System (PMS) where applicable. Use Maintenance Requirements Cards (MRCs) for preventive maintenance. MRCs provide step−by−step procedures for preventive maintenance, while the description in this manual is more general in nature. Normal underway and in−port maintenance is discussed in paragraphs 223−5.5.2 through 223−5.5.7. Maintenance during periods of new construction, overhaul, and extended availability are discussed in paragraphs 223−5.5.8 through 223−5.5.13.

223−5.1.2 IMPORTANT POINTS IN MAINTENANCE. Experience indicates that the most important points involved in keeping a battery in good condition are as follows:

a. Regularly bring each cell up to full specific gravity and voltage by means of equalizing charges (section 223−3.2.8, paragraph b). Equalizing charges minimize inequalities among battery cells. Ensure that all cells are regularly restored to uniform, maximum capacity and prevent formation of abnormal sulfate (paragraph 223−6.4.2).

b. Keep condition of battery cells as uniform as possible (paragraph 223−5.1.2.1).

c. Work battery in a way that conserves battery life (paragraph 223−5.1.2.2).

d. Water batteries as required (paragraph 223−5.3.3).

e. Check purity of electrolyte annually (paragraph 223−5.5.5).

f. Do not adjust specific gravity or renew electrolyte without Naval Sea Systems Command (NAVSEA) authorization, except as required in paragraph 223−5.3.4.11.

g. Take proper care of inactive batteries (paragraphs 223−5.1.2.9 223−3.6).

h. Keep batteries clean (paragraph 223−5.5.1).

i. Expedite ventilation repairs (paragraph 223−5.2.4).

j. Check meters as required by the Metrology Requirements List (METRL) (paragraph 223−5.5.2).

k. Check hydrometers quarterly (paragraph 223−5.5.3).

l. Check battery capacity semiannually (paragraph 223−5.5.4).

m. Follow regular routine (paragraph 223−5.5.6).

n. Maintain records, drawings and instruction books (paragraph 223−5.5.6.4).

o. Check thermometers semiannually (paragraph 223−5.3.4.8).

223−5.1.2.1 Maintaining Battery Cell Uniformity. Every effort should be made to maintain the condition of the cells as uniform as possible, without overcharging good cells in order to hold up the low cells.

Pilot cells should be selected carefully to ensure that they will be representative of the battery as a whole, taking into account temperature differences existing in the battery. Two pilot cells should be selected for each 126 cells (128 cells for TRIDENT battery). Neither should be an end−of−row or out−

board row cell, and neither should be directly under a hatch. One of these cells should be selected from the hottest cells and one from a row adjacent to the centerline. The other cell should be an average−temperature cell selected from the row adjacent to an outboard row, one not in the same physical half of the battery as the center−row pilot cell.

Example: If the first pilot cell (selected from the hottest cells) is in the forward port quadrant, then the second pilot cell will be in the aft starboard quadrant.

Following new battery installation and after three equalizing charges have been conducted to establish a trend in overall individual cell readings, ship's force should carefully review the equalizing charge data. This is to ensure that the initially selected pilot cells still meet the requirements of paragraph 223−5.1.2.1

223−5.1.2.2 Working of Battery to Conserve Life. To be considered are the guarantee, usage rate, overcharge, trickle−discharge, electrolyte agitation, use of shore power and level of discharge (paragraphs 223−5.1.2.3 through 223−5.1.2.8).

223−5.1.2.3 Calendar Life and Cycle Life Guarantees. The lead−calcium battery is a long−calendar, low−cycle life battery. Generally the batteries are replaced because of age in months. The GUPPY I Mod C battery is guaranteed for 66 months or 165 equivalent cycles, the GUPPY I Mod E battery is guaranteed for 66 months or 165 equivalent cycles and the TRIDENT battery is guaranteed for 72 months or 200 equivalent cycles. (Equivalent cycles are defined in paragraph 223−3.1.11)

223−5.1.2.4 The Usage Rate. The usage rate reflects the working of the battery. The usage rate for GUPPY I Mod C is approximately two cycles per month.

223−5.1.2.5 Percent Overcharge. The calcium grid battery is efficient and requires only five to 10 percent overcharge. If overcharge, as indicated by the ampere−hour (Ah) meter exceeds 10 percent, ammeters and ampere−hour meter should be calibrated.

223−5.1.2.6 Trickle−discharge Operation. Although the ideal situation for calcium grid batteries might seem to be positively floating the charge just above the open circuit voltage, continuous positive floating has, in some instances, produced irreversibly harmful results. In order to maintain calcium grid batteries, it is necessary to trickle−discharge them at approximately five amperes for GUPPY I Mod C, seven amperes for GUPPY I Mod E and 10 amperes for TRIDENT until they are discharged approximately 1000 Ah for GUPPY I Mod C, 1400 GUPPY I Mod E and 2000 Ah for TRIDENT, after which they are to be recharged. Prior to a scheduled equalizing charge, when the battery is not in the trickle−discharge mode of operation, it is not necessary to accomplish the trickle−discharge routine just to satisfy this requirement. If for any reason the battery is discharged more than 4000 Ah for GUPPY I Mod C, 5400 for GUPPY I Mod E, and 7500 Ah for TRIDENT, an equalizing charge must follow as soon as possible.

NOTE

A battery should not be allowed to remain in a state of discharge below 1.150 specific gravity for more than 24 hours.

223−5.1.2.7 Electrolyte Agitation. Agitation system maintenance and inspections are critical for calcium grid battery installations. The system should be kept in continuous operation to gain maximum benefit.

223−5.1.2.8 Use of Shore Power. Battery life will be conserved if shore power is used whenever possible to satisfy auxiliary power and lighting loads.

223−5.1.2.9 Care During Inactive Periods. Battery operation during inactive periods (that is, construction, overhaul and extended availability) should be in accordance with paragraph 223−3.6. Maintenance should be in accordance with paragraphs 223−5.5.8 through 223−5.5.13.

223−5.1.2.10 Freshening Charges. Freshening charge instructions apply to any battery shipped in the dry condition, filled and charged at the building yard or Naval shipyard, and not yet installed. A freshening charge is a charge given to restore the fully charged condition of an idle battery that has lost part of its capacity by self−discharge. Unless otherwise specified on the approved manufacturer's instructions, the freshening charge rate is the same as the finishing rate shown on the curves and data plan for the type of battery. Freshening charges shall not normally be given to an installed battery until the ventilation system is completely installed (including hydrogen detectors and airflow meter) and tested for air quantity and distribution within the battery tanks (paragraph 223−5.2.4). Freshening charges onboard ship shall be conducted in accordance with the manufacturer's instructions as approved by NAVSEA. These instructions should be on hand prior to the arrival of the battery. If no instructions have been received within 30 days of battery arrival, the supervisor of shipbuilding, in the case of a private shipyard, or the Shipyard Commander, in the case of Naval shipyard, shall request such instructions from NAVSEA.

223−5.2 EQUIPMENT MAINTENANCE

223−5.2.1 ION EXCHANGERS. Use PMS and MRCs as applicable in maintaining ion exchangers.

223−5.2.1.1 Resin Renewal Schedule. Under average operating conditions, the mixed−bed ion exchange resin should be replaced every 30 days. It is not practical to regenerate this material in the field. If a sharp rise in salinity is shown on the salinity meter before 30 days have elapsed, check to be sure that the proper flowrate is being maintained. If the proper flowrate is being maintained and the salinity becomes excessive, with the salinity indicator showing one milligram per liter (0.06 grains per gallon) or 0.17 equivalent parts per million (epm), replace the resin using MRC EL−18 R−4 as a guide. The salinity should then drop to a very low value.

223−5.2.2 FLASH ARRESTERS. Flash arrester domes can be expected to become clogged in time by an accumulation of dirt and electrolyte spray and are also known to lose their nonwetting or water repellent property with time. They should be cleaned and tested whenever necessary prior to a hydrogen survey, but at least once every six months. A procedure has been developed for retreating used flash arresters to restore their nonwetting or water repelling properties (paragraph 223−7.2.3).

223−5.2.2.1 Inspection and Replacement. During removal and reinstallation for semiannual maintenance, inspect each flash arrester for cracks, espe−

cially at the dome/base interface. Replace units as necessary.

223−5.2.2.2 Cleaning. A step−by−step procedure for cleaning flash arresters is provided in MRC EL−18 S−4. Place flash arresters, open end down, in a distilled water bath, which is put in an ultrasonic tank and agitated for 30 minutes. Repeat the above procedure using a fresh, distilled water bath. Dry flash arresters, open end down, at a temperature of 82°C (180°F) for 60 minutes after cleaning. While not as simple as ultrasonic cleaning, three immersions in freshwater (each followed by drying with an air blast) is also a satisfactory cleaning method. After cleaning, some arresters lose their water repellent properties, as evidenced by a large pressure drop when subjected to the wet pressure drop test.

223−5.2.2.3 Wet Pressure Drop Test. A step−by−step procedure for the wet pressure drop test is provided in MRC EL−18 S−4. After each arrester is cleaned, or at any time there is doubt that any arrester is venting gas adequately, perform this test. The test apparatus is shown schematically in Figure 223−34. This apparatus can be constructed simply and inexpensively locally.

a. Submerge flash arrester(s) to be tested in distilled water for 15 minutes.

b. Remove from water and thread into test apparatus, ensuring that neither the apparatus nor the arrester O−ring leaks.

c. Between five and 10 minutes after removal from water, pass air through each flash arrester dome at the rate of 10 + 0.2 liters (0.35 + 0.005 ft^3) per minute. With air passing through the dome at the above rate, the pressure drop across the dome after five seconds must not exceed 500 pascals (50 millimeters of water) or the arrester fails the pressure drop test.

223−5.2.2.4 Water Repellent Treatment. Flash arresters that do not pass the test described in paragraph 223−5.2.2.3 probably have lost their nonwetting or water repellent feature. This feature can be restored if the flash arrester is treated with the procedure outlined in paragraphs 223−7.2.3.1 through 223−7.2.3.5.

223−5.2.3 HYDROGEN DETECTORS. Maintenance of the Englehard Hydrogen Detector is thoroughly covered in the manufacturer's service manual and NAVSEA 0387−LP−026−1000, Indicators. The life of installed sensing units exceeds three years. In order to prolong sensing unit life and to maintain the accuracy of indication with a minimum of recalibration, the detector should be left ON at all times except when it may be necessary to turn it OFF for maintenance, overhaul, construction or upkeep.

NOTE

Defective sensing units should be turned into supply when replacements are requisitioned.

223−5.2.4 TEMPORARY BATTERY VENTILATION SYSTEM. When repairs necessitate the temporary dismantling of the battery ventilation system, the repair schedule should restore the permanent battery ventilation system in time to make prescribed charges. Under ordinary conditions, charging shall not be done until the ventilation system has been completely installed and tested for air quantity and distribution. Any deviation is considered an emergency, requiring extreme care. The minimum requirements for temporary battery ventilation are set forth in Section 4, when charging is absolutely necessary under such conditions of temporary deviation from normal conditions of ventilation.

223−5.3 BATTERY WATER AND ELECTROLYTE

223−5.3.1 NEED FOR PURE BATTERY WATER. In normal operation, no acid is lost from the electrolyte in the lead acid cell and none need be added. Water, however, is lost from the electrolyte by evaporation and electrolysis (which accompany ventilation and charging) and must be replaced to maintain the electrolyte at the proper level. Lead−calcium batteries lose minimal amounts of water because operation above the gassing potential is practically nonexistent. Any impurities in the added water remain in the electrolyte. It is apparent, therefore, that the purity of the water added to a cell during operation is just as important as the purity of the water used in preparing the electrolyte. Consequently, only pure, distilled water, satisfying all requirements of paragraph 223−2.9.2.3, should be added to a storage battery cell. In case water meeting these requirements is positively unobtainable onboard ships or from a shore facility, only the purest water obtainable shall be used for battery watering. Whenever possible, water from an uncommon source shall be analyzed prior to use and the analysis shall be entered in the battery record book. Water that does not meet all requirements of paragraph 223−2.9.2.3 shall be removed from ship's demineralized (DI) water header at the earliest opportunity and replaced with water that does.

223−5.3.1.1 Water Analysis. Only a complete analysis by a qualified chemist can determine whether the water is in compliance with paragraph 223−2.9.2.3. Shipboard testing is for determining only whether the water has been contaminated by seawater (in which the main impurity is sodium chloride). Hence, the tests are based on the maximum chloride concentration allowed by paragraph 223−2.9.2.3. The rest is discussed in paragraphs 223−5.3.2 through 223−5.3.2.4. It is assumed that metallic impurities will be removed in passing through the ion exchangers. Experience indicates that water passing the chloride test and passed through an ion exchanger is satisfactory for use in batteries. Material other than water shall not be added to battery cells except as authorized in paragraphs 223−5.3.4.11 and 223−5.5.5.

223−5.3.1.2 Water Handling System. Piping, fittings and portable tanks used for the transportation of DI water shall be hard rubber, plastic [that is, Saran (polyvinyl chloride)] or lead (or lead−lined), except that valves may be brass. Nickel, nickel−plated or nickel alloy piping and fittings shall not be used in this system.

223−5.3.1.3 Water Storage. Water for use in batteries shall be stored onboard ships in the ship's DI water tank or in clean containers as described in section 223−5.3.1.2.

223−5.3.2 TESTS FOR CHLORIDES PRIOR TO USING DI WATER. Regardless of its source, DI water shall be tested for the presence of chlorides immediately before it is placed in the ship's water tanks or in a cell (to replace water lost by evaporation and electrolysis). The test described in paragraph 223−5.3.2.1 is required in addition to any other tests required in this volume. Test samples should be taken from the discharge end of the watering hose. Before taking samples, be sure to run off and discard at least 20 liters of the DI water. This will preclude the possibility of sampling only the water in the hose. In addition, loose particles of ion exchanger resin will be washed out by this flushing operation, thereby ensuring that the sample will be clear.

223−5.3.2.1 Silver Nitrate Test for Chlorides. The following solutions and equipment shall be carried aboard ship to make shipboard tests for chloride in DI water (paragraph 223−2.9.2.3):

a. One liter (approximately one quart) of silver nitrate solution (see paragraph 223−5.3.2.4 for instructions on preparation of the solution).

b. Two liters (two quarts) of a comparison solution containing five ppm, by weight, chlorine as chlorides. (Pure distilled water with 0.00815 grams of sodium chloride per liter will contain the desired percentage of chlorine. This solution should be prepared by a chemist).

c. Two liters (approximately two quarts) of a comparison solution containing 120 ppm, by weight, chlorine as chlorides. (Pure distilled water containing 0.198 grams of sodium chloride per liter contains the desired percentage of chlorine. This solution should be prepared by a chemist).

d. Several test tubes of the same size and shape.

223−5.3.2.2 Initial Test. To test battery water for chlorides, thoroughly wash a test tube with DI water, place about 20 milliliters (one fluid ounce) of the water to be tested in the test tube, add about two milliliters (0.1 fluid ounce) of the silver nitrate solution and shake thoroughly to mix. The exact quantities of battery water and test solution used are not important, but care should be taken while shaking not to close the top of the test tube with a thumb or a stopper, as this might introduce additional salt and invalidate the test. If the battery water remains clear after the addition of silver nitrate, the chloride content is satisfactory. If the water becomes slightly turbid and assumes a faintly milky appearance, a further test should be made (described in paragraph 223−5.3.2.3) to determine whether the chloride content is below the five ppm specified for battery water (paragraph 223−2.9.2.3).

223−5.3.2.3 Final Test. Thoroughly wash two test tubes with DI water and drain. Then place about 20 milliliter (one fluid ounce) of DI water in one, and an equal amount of the five ppm percent comparison solution in the other test tube. Add about two milliliters (0.1 fluid ounce) of the silver nitrate solution to each and shake.

NOTE

> Take care to add the silver nitrate to each of the two test tubes at as nearly the same time as possible, since the turbidity produced increases upon standing and an accurate comparison can be made only when the two solutions stand for the same length of time.

Wait for two or three minutes, then visually compare the solutions in the two tubes. The one with more turbidity has the greater chloride content. If the battery water is clearer than the comparison solution, it has less than five ppm chloride content.

223−5.3.2.4 Silver Nitrate Solution for Chloride Test. The silver nitrate solution used for testing chlorides (paragraphs 223−5.3.2.1 and 223−6.5.2.4) is prepared by putting 28.3 grams (one ounce) of silver nitrate crystals [issued in 28.3 gram (one ounce) bottles], into an amber−colored glass bottle that has been thoroughly cleaned and rinsed with DI water. The bottle must be made of amber or brown glass, not clear glass. Add 470 cubic centimeters (16 ounces) of DI water and, without inserting the stopper, agitate the bottle until the crystals are completely dissolved. Allow the solution to stand for 15 minutes, then fill a test tube with the solution and examine. If the solution is clear, it is satisfactory for the chloride test. If the solution is cloudy, discard it, thoroughly clean the bottle, rinse with DI water and make up a fresh solution. If the second batch of solution is cloudy, allow it to stand for at least 24 hours, then decant or siphon off the clear liquid in the upper part of the bottle into another amber bottle. The bottle containing the solution should be kept tightly stoppered. For siphoning, be sure to use a glass tube, bent into the form of a siphon, that has been thoroughly cleaned and rinsed with DI water before use. Fill a test tube with solution from the second bottle and examine to ensure it is clear.

223−5.3.3 WATERING REQUIREMENTS. Battery cells shall be watered as often as necessary to ensure that the electrolyte level does not fall below the minimum level specified on the curves and data plan in the battery manufacturer’s technical manual. After initial battery installation, watering frequency can be determined only by maintaining a close watch on the electrolyte height, especially of those cells that, upon reinspection, have shown the greatest water loss.

The electrolyte level of each pilot cell must be ascertained daily. After initial battery installation, watering of the battery should not precede the first equalizing charge.

223−5.3.3.1 Adding Water to a Cell. Whenever practical, add replacement DI water preceding an equalizing charge so that the water will mix with the electrolyte during charge, but not prior to the first equalizing charge. When this is done, take specific gravity readings just prior to watering and, after correcting for temperature, record the reading as the corrected specific gravity at the start of the charge. Be careful not to fill any cell above the normal level when watering. An abnormally high level will result in loss of electrolyte by overflow from the cell. This condition is particularly aggravated when the cell is gassing freely at the finishing rate, since the electrolyte level may then be as much as 50 millimeters (mm) [two inches] above the level at the start of the charge.

223−5.3.3.2 Abnormal Level Changes. Note any cells requiring an excessive amount of water; jars of these cells should be watched for leaks. Watering cells to a level below the normal level is highly advisable when an abnormal rise in electrolyte level occurs during charge. The rise in level diminishes as new cells are worked and it is safe to water to normal level if the rise does not exceed 25 mm (one inch).

223−5.3.3.3 Agitation Requirements. The electrolyte agitation system should always be in operation before, during and after adding DI water to allow for proper mixing of electrolyte. Watering that is not followed by a sufficiently long gassing charge will initially create a layer of very dilute electrolyte above the top of the plates. This layer will invalidate hydrometer readings. Therefore, when it is known that a gassing charge will not be given, omit watering as long as the electrolyte height is above the minimum level. See paragraph 223−5.5.11 for watering during inactive periods.

223−5.3.3.4 Temperature of Electrolyte When Watering. Adding water to a normal level is advisable only when the electrolyte temperature is 18°C (65°F) or greater. If it is necessary to add DI water at lower electrolyte temperatures, add to the minimum level specified by the applicable service manual.

223−5.3.4 SPECIFIC GRAVITY MEASUREMENTS AND CORRECTIONS. The specific gravity should be measured in accordance with section 223−3.1.6.1. Hydrometer readings must be corrected for the temperature of electrolyte when they are to be used as a measure of the state of charge since they depend upon the following three factors, of which only the first furnishes a direct measure of the state of charge:

a. The weight of sulfuric acid in the electrolyte

b. The temperature of the electrolyte

c. The volume or height of electrolyte in the cell.

223−5.3.4.1 Correction for Temperature. Hydrometers for naval use are calibrated to read correctly when the electrolyte temperature is 26.7°C (80°F). To correct for other temperatures: add 0.001 (1 point) to the hydrometer reading for each 1.7°C (3°F) the electrolyte temperature is above 26.7°C (80°F); subtract 0.001 from the hydrometer reading for each 1.7°C (3°F) the electrolyte temperature is below 26.7°C (80°F). Helpful information is given in Table 223−9 (also see paragraph 223−3.1.6.2).

223−5.3.4.2 Correction for Height of Electrolyte. Lead−calcium batteries are corrected for height only when the state of charge is to be determined on a partially discharged battery per procedures specified in section 223−5.3.3.1.

223−5.3.4.3 Height Readings. Lead−calcium batteries are not subject to continuous cycling. This, combined with efficient charging, will cause the amount of water loss to be minimal. The need to take and record electrolyte height readings at any time, except where overall readings are required or to determine the state of charge on a partially discharged battery, has almost been eliminated for lead−calcium batteries, as has the need for height correction of specific gravity readings.

223−5.3.4.4 Precautions in Taking Hydrometer Readings. In taking hydrometer readings, give the electrolyte in the hydrometer barrel time to settle to avoid error due to the presence of gas bubbles in the electrolyte. The hydrometer reading must be taken immediately after the gas bubbles have floated out of the electrolyte in the hydrometer barrel, especially when the cell temperature is considerably different from the ambient temperature. If the electrolyte in the barrel is allowed to cool or heat up, the temperature correction will be in error. Do not allow a direct current of air to impinge against the barrel either before or while taking a reading. The rubber bulb must be completely expanded in order to avoid depressing the float. The float must be free from contact with the barrel or the top plug and floating freely in a vertical position. When taking the reading, hold the hydrometer so that the surface of the liquid in the barrel is at eye level. This avoids the error due to the attraction between the glass and the solution. Replace the screw cap on each cell immediately after each measurement is made.

223−5.3.4.5 Use of Hydrometers. Hydrometers for storage battery use shall be used for no other purpose. All working hydrometers shall be flushed with DI water daily in order to prevent the accumulation of sticky substances inside the glass barrel. These substances gradually gather on the hydrometer float, causing the readings to be in error.

223−5.3.4.6 Selection of Hydrometers. Allowance for submarine battery test equipment is given in paragraph 223−1.9.17. The cited Allowance Equipment List (AEL) includes hydrometers of appropriate range to cover the need of any submarine. The floats selected by each submarine should be checked for accuracy at quarterly intervals (every four months for TRIDENT) (paragraph 223−5.5.3). Between quarterly checks, one accurate 1.060−1.240, and one accurate 1.228−1.316, specific gravity float should be held unused, to serve as checks against the floats in use.

223−5.3.4.7 Checking Floats. On completion of each equalizing charge, check all floats in use against unused floats of the same calibration range in one pilot cell electrolyte. The test float should be flushed with DI water prior to test. This should be done before taking sets of cell readings. All recorded specific gravities taken with the floats should be corrected for the difference between the test float reading and the working hydrometer float reading. For example, if the float used throughout the charge is found to read 0.003 specific gravity too high, subtract 0.003 from each of the pilot cell specific gravities on the rough log of the charge and from each of the individual cell specific gravities measured with this float.

223−5.3.4.8 Precautions in Taking Electrolyte Temperature Readings. The following are precautions for taking temperature readings:

a. Use of mercury−in−glass thermometers is prohibited (paragraph 223−1.9.9) in all submarines.

b. Thermometers for storage battery use shall be used for no other purpose. Working thermometers shall be washed in DI water daily and wiped dry with a clean cloth.

c. To obtain accurate temperature readings with the Weston−dial type thermometer, the stem of the thermometer must extend at least 32 mm (1−1/4 in.) into the electrolyte.

d. Close service opening on each cell by replacing screwcap after each measurement is made.

e. Preferably prior to each test discharge, or at least semiannually, check the Weston−dial thermometer for accuracy. Calibrate (paragraph 223−5.5.2.1), if necessary.

223−5.3.4.9 Interpretation of Corrected Specific Gravity. Hydrometer readings give the uncorrected specific gravity of the electrolyte above the plates. When the corrections for temperature of electrolyte are applied, the corrected specific gravity obtained is also that of the electrolyte above the plates. If the electrolyte is not uniformly mixed, the corrected specific gravity does not represent the true state of charge or discharge. When the cell is on charge, electrolyte is not uniformly mixed until the cell has been gassing freely for some time. Until then, the corrected specific gravity of the electrolyte above the plates is lower than the average for the whole body of electrolyte. This is particularly true with cells having glass mat retainers that restrict acid circulation. In this case, the cell is more fully charged than is indicated by the corrected specific gravity. When the cell is on discharge, the electrolyte tends to mix by natural diffusion. However, this takes time; consequently, the corrected specific gravity of the electrolyte above the plates is higher than the average for the whole body of electrolyte. In this case, the cell is more completely discharged than is indicated by the corrected specific gravity. The amount of error on discharge is small on rates lower than the 20−hour rate. Electrolyte agitation systems reduce the error even at the higher rates.

223−5.3.4.10 Range of Specific Gravity of Electrolyte. Electrolyte specific gravity range shall be as shown in Table 223−15.

223−5.3.4.11 Adjustment (Spiking) of Specific Gravity. No adjustment (spiking) of the specific gravity should be necessary during normal operation. The specific gravity of the electrolyte shall not be raised in any cell by the addition of acid without authority from NAVSEA. In case the specific gravity of some cells, or of the battery as a whole, should remain less than the minimum [even after adequate treatment has been given to ensure against sulfation (paragraph 223−6.4.2), a request should be made to NAVSEA for authority to increase or maintain the specific gravity. This request should contain a brief statement of the treatment given and individual voltage and specific gravity readings of each cell upon completion of six successive equalizing charges. The charging current at which these individual voltage readings are taken shall be stated.

223−5.4 ELECTROLYTE AGITATION SYSTEM

223−5.4.1 GENERAL. The agitation system in each cell should be functioning at all times to prevent electrolyte stratification. Experience indicates that lead−calcium battery airlift pumps clog easily due to calcium sulfate deposits at the bottom of the air agitation tube. The use of lampblack as an expander in the negative plate usually causes these deposits to appear black in color.

223−5.4.2 FUNCTIONAL CHECK. In the case of the GUPPY I Mod C the functioning of the individual agitators can be checked by looking into the cell top to see if electrolyte is being discharged from the top of the air agitation tube to form a fluid spout approximately 10 mm to 20 mm (1/2 to 3/4 inch) in height. To accomplish this, the flash arrester must be removed. It is not sufficient to listen over the cell for a gurgling sound, since the pumps can gurgle even though the rate of actual liquid pumping is very low. In the case of the TRIDENT and GUPPY I Mod E batteries there is no visible fluid spout. Proper functioning of the air agitation system may be verified by checking for air/electrolyte mixture (air bubbles) flowing in the plastic tubing or trough connected to the air pump barrel. Functioning of the agitators can also be checked by taking specific gravity readings. Following a charge, a cell with a properly functioning agitator will show a more rapid specific gravity rise than a similar cell without the agitator. This is particularly noticeable when cells have been watered prior to the charge. Routine maintenance of the agitation system is described in paragraph 223−5.4.3.

NOTE

For USS DOLPHIN, consult the battery manufacturer's technical manual, section 223−6.3.2, for proper verification procedures.

223−5.4.3 ROUTINE MAINTENANCE. Check all cells at least once each quarter. In planning systematic maintenance, select (for every 126 cells) cells 1 through 10 the first week, 11 through 20 the second week, and so on in 12 groups of 10 cells, with the thirteenth group being cells 121 through 126 (or 128 for TRIDENT). Unless an agitation system malfunction is suspected, no cell should be checked twice until all cells have been checked. Conduct maintenance once each week.

Table 223−15. RANGE OF SPECIFIC GRAVITY

Nominal	Operating		Initial	Charge
SP GP	Min.	Max.	Min.	Max.
1.285	1.275	1.295	1.280	1.290
1.295	1.285	1.305	1.290	1.300

223−5.4.3.1 GUPPY I Batteries. A step−by−step procedure for checking the agitation system of lead−calcium batteries is provided in MRC EL−18 W−1. The step−by−step cleaning procedures are provided in MRC EL−18 U−1. Calcium grid batteries currently in service are maintained as follows:

1. Ensure that the agitation system has been operating for at least one hour.

2. Remove flash arrester and inspect O−ring or gasket for damage or deterioration. Ventilate during inspection according to paragraph 223−4.3.2.9.

WARNING

Take particular care to prevent sparks from reaching the cell while the flash arrester dome is not in place.

3. Ensure proper agitation pumping action through procedures listed in paragraph 223−5.4.2.

4. If agitation is not satisfactory, verify total system airflow rate (paragraph 223−3.4.2.

5. If agitation remains unsatisfactory, remove the air supply tube from the cell and inspect for clogging or crimping. Replace if necessary. Do not clear away foreign material or obstructions, as experience shows that a cleaned and reused tube may clog again in two to three weeks, while a new tube may never clog.

6. If agitation remains unsatisfactory, check hose connection and throttling orifices; clear any obstructions.

7. If electrolyte flow is still insufficient, remove the air supply tube, put on rubber gloves to protect hands from electrolyte and feed a Teflon rod through both sides of the air lift pump barrel until rod comes to rest on the bottom of the cell jar. The Teflon rod will not enter into the lift side of the pump barrel on GUPPY I Mod E due to the funnel assembly. Reinstall the air supply tube. The Teflon rod is available under NSN 9G 9330−00−781−7851 from the Defense Supply Agency in Richmond, Virginia.

CAUTION

Feed the Telflon rod just far enough into the pump barrel to reach the bottom of the jar. Excessive penetration can cause separator damage at the bottom of the cell.

223−5.4.3.2 TRIDENT Batteries. TRIDENT cells have two air agitation pumps. A step−by−step procedure for checking the agitation system is provided in MRC EL−18 W−2. The step−by−step cleaning procedure is provided in MRC EL−18 U−2.

Maintenance is identical to that for GUPPY I batteries (paragraph 223−5.4.3.1).

223−5.4.3.3 DOLPHIN Battery. A step−by−step procedure for checking the agitation system for lead−antimony batteries is provided in MRC EL−18 W−1. The step−by−step cleaning procedures are provided in MRC EL−18 U−1. In addition, observe the following:

1. Ensure that the agitation system has been operating for at least one hour.

2. Remove flash arrester and inspect O−ring or gasket for damage or deterioration. Ventilate during inspection according to paragraph 223−4.3.2.9.

3. Check for proper pumping action by observing a fluid spout approximately 10 mm to 20 mm (1/2 to 3/4 in.) in height. Use an inspection mirror if necessary.

WARNING

Take particular care to prevent sparks from reaching the cell while the flash arrester dome is not in place.

4. If spout height is out of range, verify total system airflow rate.

5. If spout height remains out of range, check hose connection and throttling orifices; clear any obstructions.

6. If proper fluid spout height is still not attained, remove the air supply tube from the cell and inspect for clogging or crimping. Replace if necessary. Do not clear foreign material or obstruction, as experience shows that a cleaned and reused tube may clog again in two to three weeks, while a new tube may never clog.

7. If proper flow is still not restored, remove the air supply tube, put on rubber gloves to protect hands from electrolyte and feed a long Teflon rod through one side of the figure−eight airlift pump barrel until the rod strikes the jar bottom. Determine the exact length to the bottom of the jar from drawings in the battery service manual since excessive penetration could cause separator damage at the bottom of the cell. Repeat this procedure for the other side of the figure−eight and reinstall the air supply tube. The Teflon rod is available under NSN 9G 9330−00−781−7851 from the Defense Supply Agency in Richmond, Virginia.

CAUTION

Use of any type of wrench to tighten the coupling nut threaded into the cell cover is prohibited. The coupling nut should be hand−tightened to prevent crimping the air supply tube or cracking the cell cover.

223−5.4.3.4 Low Specific Gravity. If any cell shows a specific gravity more than 10 points below average on completion of an equalizing charge, check for proper agitation in accordance with paragraph 223−5.4.2, correct for clogging as necessary. Cell should not be on charge when dome is removed. The check need not be performed if this cell was one of those inspected before charge. Once a cell is checked, it need not be checked again until the next quarter, even if it is in a group that will be checked during the current quarter (paragraph 223−5.4.3).

223−5.5 MAINTENANCE CHECKS

223−5.5.1 BATTERY CLEANING. Step−by−step battery cleaning procedures are provided in MRC EL−18 Q−6. It is important in taking hydrometer readings and in watering a battery to avoid spilling acid on the tops of cells or on the deck covering. It is imperative that batteries be kept clean. Collection of acid or dirt around a battery will lead to troublesome grounds and may cause corrosion. A drop in ground resistance to below 100,000 ohms is usually due to a dirty battery. After each watering, wipe the tops of the cells clean and, where possible, the sides of jars. If acid has accumulated, remove it by means of a lint−free cloth, dampened with a solution of baking soda (that contains no more than 30 grams/liter of baking soda) followed by one dampened with DI water.

223−5.5.1.1 Emptying and Cleaning Sumps and Tanks. After each watering, pump out any water or acid present in battery−tank sumps and determine its source. A leaking jar is a likely source of acid in sumps. Such cells should be located and replaced if possible; otherwise, they should be jumpered out of the battery. Never clean battery tanks by flushing with water unless acid has accumulated in the tanks. Keep tank dry to avoid grounds.

223−5.5.1.2 Aluminum Oxide Deposits. Placing service caps or other cover hardware on flash arrester domes and then placing the caps or hardware on top of cell covers during a cell inspection may result in deposits of alumina on cell cover. Deposits are white in color and very difficult to remove. Although these deposits are not harmful, placing hardware on top of cell covers should be avoided.

223−5.5.1.3 Care of Individual Cell Voltage (ICV) Cabling. Every calendar quarter, when the battery well is cleaned and inspected, the ICV cabling should be inspected. Several battery well fires have resulted from faulty ICV cabling. A thorough inspection should be conducted after any work on the ICV cabling system has been done and after jumpering a cell. Inspect ICV cable runs for proper bundling; ensure that cable runs are securely fastened in standoffs to prevent sagging or rubbing motion that may fray leads. Inspect ICV conductors between points where they are connected to a bus and where they leave the cable run for clearance from energized busses, intercell connectors and attaching hardware. The initial inspection after installation or jumpering a cell should verify that ICV conductors are installed in accordance with clearance and creepage standards of paragraph 223−2.11.11 and **NSTM Chapter 300, Electric Plant General**.

223−5.5.2 METER CALIBRATION. To ensure that the operation and maintenance of storage batteries will be assisted by accurate and reliable data, meters shall be calibrated as required by the METRL, NAVSEA OD 45845. Meter calibrations are also required when data reviews by NAVSEA or the manufacturer’s service engineer reveal possible meter problems. When calibrating meters, particular attention should be paid to the condition of permanent meter connections. This is particularly true in the case of individual cell analog (nondigital) voltmeters where loose or corroded connections at the meters or in the fuse bug boxes will greatly influence meter accuracy. The meters to be calibrated are:

a. Generator armature analog ammeters

b. Main storage battery analog ammeters

c. Main storage battery analog Ah meters (analog Ah meters should be checked with a calibrated ammeter registering constant current over a measured time interval)

d. Auxiliary power ammeters

e. Generator voltmeters

f. Main storage battery voltmeters

g. Main storage battery individual cell voltmeters

h. Airflow meters in the battery ventilation system

i. ICV panel voltmeter, per NAVAIR 17−35CG−03−127

j. Electric plant control panel (EPCP) voltmeter

k. Meters used in connection with submarine battery charging, onboard tenders and at bases.

223−5.5.2.1 Thermometers. Calibration of Weston−dial thermometers should be checked semiannually.

223−5.5.2.2 Hydrogen Detectors. Calibration of hydrogen detectors shall be checked prior to each equalizing charge in accordance with Section 4 instructions.

223−5.5.2.3 Reporting Results. Accomplishment of all meter calibrations shall be included in the Quarterly Battery Report (QBR) as described in section 223−5.5.6.3.

223−5.5.3 QUARTERLY CHECK OF HYDROMETERS. Standard hydrometers used in connection with main storage battery installations shall be checked every three months (every four months for TRIDENT) for accuracy by submarine tender or shore−based personnel. Any hydrometer that fails calibration shall be surveyed, noted on the next submittal of NAVSEA form 9320/3 and replaced.

223−5.5.3.1 Material Required and Related Information. The material listed in Table 223−16 is required to check the accuracy of hydrometers used in the maintenance of lead acid storage batteries.

223−5.5.3.2 Hydrometer. A properly labeled hydrometer indicates the sample temperature (ST) and the reference temperature (RT) at which it is designed to read correctly as ST/RT.

223−5.5.3.3 Standard Hydrometer. A standard hydrometer is one that has been calibrated and is certified to read accurately at the sample temperature specified on the instrument. This instrument is used to determine the accuracy of working hydrometers and is not used directly for battery maintenance. The calibration of standard hydrometers must be accurate and must correspond to the National Bureau of Standards calibration.

223−5.5.3.4 Working Hydrometer. A working hydrometer is one that is used directly in battery maintenance. Check accuracy monthly or whenever an inaccuracy is suspected.

223−5.5.3.5 Test Electrolytes. Test electrolytes are solutions of sulfuric acid that are used to determine the accuracy of working hydrometers.

223−5.5.3.6 Calibration Point. A calibration point is a reading on a working hydrometer that is compared to a reading made on a standard hydrometer in the same electrolyte.

Table 223–16. MATERIAL FOR CHECKING HYDROMETERS

Item	Minimum use specifications (See note 1)	Typical equipment and sources of supply (See note 2)
Precision hydrometers	60°F/60°F (16°C/16°C) type with a maximum error of ±0.0005 specific gravity (S.G.) units S.G. range 1.060-1.130 1.020-1.190 1.180-1.250 1.240-1.310	Fisher Scientific Co. 711 Forbes Ave. Pittsburgh, PA 15219 Catalog Nos: 11.555H 11.555J 11.555K 11.555L
	80°F/60°F (26.7°C/16°C) type with a maximum error of ±0.001 S.G. units S.G. range 1.200 to 1.300	H-B Instruments Co. Philadelphia, PA 19140
Sulfuric acid	Technical grade (93%)	Fisher Scientific Co.
DI water		Prepared/procured locally
Hydrometer jar	Diameter = 50 mm Height = 375	Fisher Brand Fisher Scientific Co. Catalog No. 8-530L
Graduated cylinders and beakers	Use in preparation of test electrolyte	PYREX brand (3042) 500 ml graduated cylinder, KIMAX brand (14005) 1000 ml beaker
Constant temperature bath	Capable of controlling temperature from 60°F (16°C) to 80°F (26.7°C) within ±0.5°F (0.3°C)	Refrigerated and heated bath and circulator, Model 2095-2, FORMA Scientific, Inc., Marietta, Ohio
Thermometer	Capable of reading ±0.2°F	Double encapsulated mercury-in-glass thermometer (for tender and repair ships) Electronic Thermometer, Digital Display; YSI Thermistemp Telethermometer, Model 48, Fisher Scientific Co.

NOTE:

[1] Minimum use specifications are the principal parameters required for performance of the calibration and are included to assist in the selection of alternative sources of equipment. Satisfactory performance of alternative items shall be verified prior to use. All applicable equipment must bear evidence of current calibration.

[2] Typical equipment and sources of supply are provided to assist in the selection of types and sources of equipment. No endorsement or recommendation of any equipment, material or source of supply is made or implied by inclusion in this table.

WARNING

Do not pour water into concentrated sulfuric acid. The heat generated will cause a violent reaction. Sulfuric acid is highly corrosive. Take suitable precautions to protect the body, hands, eyes and clothing when handling sulfuric acid. Wash any spilled acid immediately with DI water and neutralize with sodium bicarbonate.

223−5.5.3.7 Preparation of Test Electrolyte. The test sulfuric acid solution must have the required nominal specific gravity to test the accuracy of a working hydrometer. The percent of concentrated sulfuric acid (by volume) required for a test electrolyte of a particular specific gravity is given in Table 223−17. Test electrolyte prepared using this information should have approximately the specific gravity stated in the table. The actual specific gravity can be measured using a standard hydrometer.

The following example illustrates the use of Table 223−17 in preparing test electrolyte.

Example: A test electrolyte solution with a specific gravity of 1.290, 16°C/16°C (60° F/60°F), is approximately 28.6 percent (by volume) concentrate (93 percent) sulfuric acid. Let V equal the volume of test electrolyte needed. The volume of sulfuric acid, V_a, required to make this amount is given by the following equation:

$$V_a = (28.6/100) \times V$$

Therefore, 138.5 ml (4.68 ounces) of concentrated (93 percent) sulfuric acid (V_a) will make 500 ml (16.9 ounces) of test electrolyte, (V). This will require approximately 361.5 ml (12.22 ounces) of DI water.

223−5.5.3.8 Mixing Test Electrolytes. The steps for producing a uniform, well−mixed test electrolyte solution are as follows:

1. Measure required amounts of acid and DI water.

2. Place DI water in a beaker and slowly add acid to the DI water. (The solution will become hot due to heat generated by mixing of the acid and water.) Allow solution to stand until it is cool. Measure amount of electrolyte solution obtained and add amount of DI water needed to obtain required amount of electrolyte. Pour test electrolyte into hydrometer cylinder and stir to mix electrolyte and remove air bubbles.

3. Place hydrometer cylinder in a constant temperature bath at temperature required for calibration. (Temperature for calibration is the sample temperature specified on the hydrometer float.) Allow hydrometer cylinder to reach the required temperature before testing hydrometers.

4. Select two calibration points for each hydrometer; one point is to be in the top one−fifth of the scale, the other is to be in the lowest one−fifth of the scale.

223−5.5.3.9 Preparation for Test of Hydrometer Floats. Before starting test, examine working and standard hydrometers for cracks and for liquid inside. If a float is damaged, discard it. Clean hydrometers by washing with soap and DI water, dry and wipe with cloth moistened with alcohol to remove any residual soap film. The standard hydrometer used should be of the same type as the working

Table 223–17. CONCENTRATIONS OF SULFURIC ACID REQUIRED TO OBTAIN TEST ELECTROLYTE WITH A PRESCRIBED SPECIFIC GRAVITY

Specific gravity	Percent by volume of 93% technical grade sulfuric acid	Specific gravity	Percent by volume of 93% technical grade sulfuric acid
1.050	4.5	1.180	17.0
1.060	5.4	1.190	18.0
1.070	6.3	1.200	19.0
1.080	7.2	1.210	20.1
1.090	8.2	1.220	21.1
1.100	9.1	1.230	22.2
1.110	10.2	1.240	23.2
1.120	11.2	1.250	24.3
1.130	12.0	1.260	25.4
1.140	13.0	1.270	26.5
1.150	14.0	1.280	27.5
1.160	15.0	1.290	28.6
1.170	16.0	1.300	29.7

hydrometer being tested. For practical purposes 16/16°C (60/60°F) standards can be used to test 26.7/16°C (80/60°F) working hydrometers without correcting for temperature; 26.7/26.7°C (80/80°F) working hydrometers can be tested using 16/16°C (60/60°F) standards by multiplying the reading obtained with the 16/16°C (60/60°F) hydrometer by 0.0017 and then adding the result to the reading obtained with the 16/16°C (60/60°F) hydrometer to obtain the correct value for the 26.7/2.67°C (80/80°F) working hydrometer.

223–5.5.3.10 Test of Hydrometer Floats. The results obtained while testing hydrometer floats should be recorded on a form similar to that shown in Figure 223–25 and should be included in the battery record book. Place standard and working hydrometer floats in hydrometer cylinder by slowly immersing them to slightly beyond the test point, allowing them to float freely. Wait three minutes for floats to reach the bath temperature. If hydrometers are of the same type, it is unnecessary to control bath temperature except to prevent rapid, irregular changes in temperature during test.

a. Read hydrometers by observing intersection of liquid surface and stem from below the surface so that surface appears as an ellipse. Adjust the hydrometer viewing angle until the ellipse becomes a straight line. The point at which this straight line intersects the stem is the correct hydrometer reading.

b. If the standard hydrometer is not within the range required by the calibration point, adjust the density of the test electrolyte to obtain the proper specific gravity. Add DI water to lower specific gravity; add concentrated acid to raise specific gravity. Mix thoroughly after each addition and allow new test electrolyte to stand at least 1/2 hour before using. Repeat the reading.

c. If reading on standard hydrometer is within required range, record the value. Read working hydrometer and record its value. Reread standard hydrometer and record its value.

d. If the first and second readings on the standard hydrometer are not within one smallest scale division of each other, stir electrolyte, discard first readings and repeat step 3.

223−5.5.3.11 Hydrometer Accuracy Requirement. The accuracy of every hydrometer covered by this volume is to be within one smallest scale division of readings obtained with the standard hydrometer. For example, if a hydrometer has a smallest scale division of 0.002, the accuracy requirement is ± 0.002 from reading obtained with standard hydrometer.

223−5.5.3.12 Criteria for Rejecting Working Hydrometers. A working hydrometer is to be rejected as inaccurate if it does not meet the accuracy requirement at either the low−range or high−range calibration points. The hydrometer will also be rejected if it is cracked, chipped, has loose ballast material inside it or has liquid inside it.

223−5.5.4 SEMIANNUAL CHECK ON BATTERY CAPACITY. Once every six months, every battery shall be completely discharged in order to determine its actual capacity. At any time, the ratio of the actual capacity to the service capacity is generally the best single indication of battery condition. The capacity discharge rate is the 3−hour rate; USS DOLPHIN discharge rate is the 6−hour rate. The initial starting temperature for a battery should never exceed 38°C (100°F) (paragraph 223−3.5.10.2). After completion of a capacity test discharge where the capacity is limited to less than 90 percent due to a faulty cell or cells, take corrective action in accordance with technical manual procedures and with the order of precedence of section 223−3.1.1 taken into account. Repeat the test discharge.

223−5.5.4.1 Minimum Percentage of Capacity Allowable. The minimum percentage of rated capacity allowable in a submarine battery is 90 percent. The battery should be replaced if the capacity, after an equalizing charge (paragraph 223−5.5.4) is less than 90 percent and cannot be increased by maintenance or corrective action. Consideration will be given to replacement prior to reaching age limits if the hydrogen evolution when submerged (paragraph 223−4.1.2.1) becomes excessive before the capacity drops below the minimum allowable level (paragraph 223−1.10.1). Notify NAVSEA by special QBR, NAVSEA form 9320/3, whenever capacity declines below 90 percent or drops more than 10 percent from the last capacity test.

223−5.5.4.2 Capacity Determination. The actual capacity of a lead−calcium battery can be determined by discharging the battery as follows:

1. If necessary, bring electrolyte to its proper level by adding DI water.
2. Give battery an equalizing charge.
3. The ampere−hour (Ah) meter, due to inaccuracies, is not used to determine total Ah of discharge. However, it is used as a check of calculated Ah and should be set to zero on completion of charge.

HYDROMETER TEST RESULTS

Description of working hydrometer floats:
Type: 80/60 (27/16), 60/60 (16/16)
Source:

Manufacturer:
Contract number:
Date procured by test solicitor:
Serial numbers of hydrometers tested:
Physical condition as received for testing, i.e., clean, dirty or cracked:

Test information:
Standard hydrometers:
Low-range calibration High-range calibration

Type
Manufacturer
Serial number

Test data:
Low range of calibration:
High range of calibration:
Required bath temperature:

	Test	**Low-range calibration**		**High-range calibration**	
Reading	**Electrolyte temperature**	**Standard hydrometer**	**Working hydrometer**	**Standard hydrometer**	**Working hydrometer**
1					
2					
3					
4					
5					

Test report:
Date of test:
Number of hydrometers received for testing:

Defective hydrometers:
Number of hydrometers physically defective:
Number of hydrometers inaccurate at the low-range calibration point:
Number of hydrometers inaccurate at the high-range calibration point:

Total number of hydrometers unsatisfactory for use:

Hydrometers acceptable for use:
Manufacturer Serial number

Figure 223−25. Sample Form for Recording Results of Hydrometer Test

4. For a particular battery installation the desired discharge rate as displayed in Table 223−18 should be used. These rates should be held constant within ± 50 amperes as read on the ammeter.

5. At the rates selected in paragraph 223−5.5.4.2, the final voltage, average final cell voltage and minimum final cell voltage are shown in Table 223−18.

6. When any limiting voltage is reached, the discharge shall be officially terminated. Time to this point shall be the actual time of discharge.

7. If the discharge rate was held constant at the specified value read on the ammeter, proceed to step 8 and determine rated time. If the discharge rate was not held constant, compute total Ah of discharge in accordance with paragraph 223−3.5.13.2. Divide the computed total Ah of discharge by actual time of discharge from step 6, preceding. The quotient is average discharge rate in amperes.

8. Refer to the battery curves and data (Figure 223−2 and Figure 223−3) and find rated duration of discharge for the average discharge rate from step 7. This rated time of discharge is then corrected for temperature based on average pilot cell electrolyte temperature existing at start of test discharge.

9. Compute percent service of Ah capacity obtained. This is equal to 100 times the actual time of discharge from step 6, divided by corrected rated time of discharge from step 8.

10. Enter results in the QBR, NAVSEA form 9320/3.

NOTE

USS DOLPHIN Maintenance Manual should be referenced for USS DOLPHIN Battery Maintenance.

223−5.5.5 ANNUAL ELECTROLYTE ANALYSIS AND CORRECTION OF IMBALANCE. Every 12 months a 150 ml (five ounces) sample of electrolyte from each group of 126 or 128 cells shall be sent to the nearest Government laboratory for spectro−analysis. The sample shall be taken from a cell that has not previously been used for this purpose and the amount of electrolyte removed for chemical analysis shall be replaced by pure electrolyte of the same specific gravity. Each sample shall be labeled to show the name of the ship, date, cell number and specific gravity, and marked ”Used Electrolyte.” The analysis shall show the parts per million (ppm) of each of the impurities listed in Table 223−19 and the specific gravity of the electrolyte at 26.7°C (80°F). The results of each analysis shall be entered in the battery record book, along with the information on the sample label.

If the analysis shows any impurity to be in excess of the amount specified in Table 223−19, the analysis should be repeated on electrolyte samples from that cell and all cells adjacent to it. If excess impurities are verified to be present in one or more cells, forward a copy of all analysis reports to NAVSEA for evaluation. If necessary, authority to renew electrolyte will be granted by NAVSEA. For effects of impurities and procedure to be followed in renewing electrolyte, see paragraphs 223−6.5 through 223−6.5.6.

223−5.5.6 BATTERY MAINTENANCE ROUTINE. The routine maintenance to be followed with a battery shall be in accordance with the PMS Maintenance Index Page applicable to the battery type installed. In addition:

a. Daily, take pilot cell readings of specific gravity, temperature, height of electrolyte and battery agitation airflow rate; take readings of battery voltage and

Table 223−18. BATTERY DISCHARGE RATES

Type	Discharge rate (3-hr) (amperes)	Final voltage	Average final cell voltage	Minimum final cell voltage
GUPPY I Mod C	1750	201V	1.61V	1.51V
GUPPY I Mod E	2400	201V	1.61V	1.51V
TRIDENT	3450	206V	1.61V	1.51V

Table 223−19. USED ELECTROLYTE IMPURITY LIMITS

Impurities	Chemical identification	Parts per million (ppm)
Copper	Cu	50.0
Iron	Fe	120.0
Manganese	Mn	0.6
Nickel	Ni	1.0
Platinum	Pt	1.0

battery grounds. Record all readings in engineering log (electrical).

b. Monthly, if addition of water is required, restore electrolyte level of all cells by adding DI water prior to a equalizing charge (see paragraphs 223−5.3.3 and 223−5.5.11). Examine ventilation system and ensure that fans operate properly and in the correct direction and that valves, dampers and blower impellers are in proper condition. Make note in the battery record book of the quantity of water used and the results of the foregoing inspection.

c. Semiannually, remove hard rubber ventilation ducts from ship and wash thoroughly with freshwater. Note condition of wax on interior of ducts and recoat if necessary. Inspect all hard rubber ducts and all soft rubber goosenecks. Inspect interior of standpipe for condition of rubber lining. Inspect ventilation dampers and battery fan impellers for corrosion. Inspect for cracked jars and covers and for loose wedging.

d. Inspect quick−opening disconnects (as described in the applicable MRC or paragraph 223−2.12) after initial installation, during each overhaul, after a battery replacement or when attached bus bars have been disturbed during other maintenance such as jumpering a defective cell.

223−5.5.6.1 Interval Cleaning. During each upkeep period, or at intervals not to exceed eight weeks, maintain battery as follows:

1. Disconnect, inspect and clean as necessary all sampling lines to main storage battery airflow meters and

hydrogen detectors. Ensure that lines are clear. Reassemble.

2. Clean out each battery ventilation fan casing drain.

3. Inspect, check operation and ensure airtight closure of battery compartment bulkhead flappers by placing a thin piece of tissue paper in front of ventilation duct, checking for airflow from battery well.

4. Clean and inspect battery. See MRC EL−18 R−1.

223−5.5.6.2 Overhaul Cleaning. At each overhaul, follow instructions covering operation of installed batteries during overhaul contained in the applicable manufacturer's technical manual, Section 3 and Section 5. Check all accessory equipment to ensure safe and efficient operation subsequent to the overhaul. Perform all battery compartment ventilation system tests required by section 223−4.6. Clean and test all flash arresters (paragraphs 223−5.2.2 and 223−5.5.10). Examine and replace (if necessary) orifices in agitation lines. Regenerate or replace ion exchange resin, if necessary. Torque all intercell nuts and bolts to 500−550 inch−pounds (57−62 newton−meters). Follow MRC EL−18 R−3. Inspect quick−opening disconnects for proper bus bar alignment and surface contact (paragraph 223−2.12).

223−5.5.6.3 Quarterly Report. Quarterly, submit battery report on Form NAVSEA 9320/3, Figure 223−16, one copy to each of the following: NAVSEA Code 56Z33, Force Commander, Squadron Commander, Mare Island Naval Shipyard Code 134.13 and the manufacturer. Report on the calibration check on hydrometers, hydrogen detectors, airflow meters and electrical meters. In Remarks section, if ampere−hour meters have not been checked, report the reason and the date this check will be accomplished. Specific gravity measurements should be made to three significant digits, cell voltage measurements to two significant digits, total corrected voltage measurements to one digit, temperature reading to zero significant digits and all other readings to two significant digits.

223−5.5.6.4 Records, Drawings and Instruction Books. The battery record book is the official log of the battery. It must be kept in accordance with the instructions contained therein. In addition, a complete set of battery drawings and an instruction book should be available on each submarine. Ships not possessing a full set should request them from NAVSEA. Battery drawings and instruction books should not be requested from the manufacturer or contractor. The battery record book is retained for the lifetime of the battery.

223−5.5.7 ACTION AND REPORTS REQUIRED. The following is a summary of important paragraphs requiring action, reports on action taken or notification of action to be taken by shipyard or ship's personnel:

a. If cell shipping damage is known or suspected, notify carrier (paragraph 223−2.3.2).

b. Notify battery manufacturer of initial inspection date (paragraph 223−2.3.2).

c. Notify cognizant Defense Contract Administration Services (DCAS) representative when battery is to be placed in service and installed (paragraph 223−2.8.1.1).

d. Forward sample of filling electrolyte to a Government laboratory for analysis prior to use (paragraph 223−2.9.2.6).

e. Forward a sample of electrolyte taken from each pilot cell before installation to a Government laboratory for analysis (paragraph 223−2.10.6).

f. Report on initial cycles (paragraph 223−2.10.7).

g. Report overhaul on battery and related systems (paragraph 223−8.6.2).

h. Report results of meter calibration on Form NAVSEA 9320/3 (paragraph 223−5.5.2).

i. Report results of quarterly check on hydrometers on Form NAVSEA 9320/3 (paragraph 223−5.5.3).

j. Report results of semiannual test discharge on Form NAVSEA 9320/3 (paragraph 223−5.5.4).

k. Submit submarine battery quarterly report on Form NAVSEA 9320/3 (paragraph 223−5.5.6.3).

l. Submit ventilation systems reports (paragraph 223−4.6.9).

223−5.5.8 MAINTENANCE DURING NEW CONSTRUCTION, OVERHAUL AND EXTENDED AVAILABILITY. During periods of new construction, overhaul and extended availability, the battery is operated in accordance with paragraph 223−3.6.3, if authorized in accordance with paragraph 223−3.6.2. During these authorized operations, routine battery maintenance shall be in accordance with paragraphs 223−5.1 through 223−5.5.7, except as modified by paragraphs 223−5.5.9 through 223−5.5.13 below.

223−5.5.9 ELECTROLYTE AIR AGITATION SYSTEM. The system is operated as required by Section 3. When the system is placed in operation to support a battery charge, the functional check described in paragraph 223−5.4.2 shall be accomplished in all cells. If the system is being operated continuously, maintenance shall be in accordance with paragraph 223−5.4.3.

CAUTION

> Before taking on shore power, deenergize the air agitation system blower/motor. If electrical phases are inadvertently reversed, the blower/motor will reverse rotation, take a suction on battery cells and contaminate the air system piping.

After verifying proper electrical phasing, reenergize the blower/motor.

223−5.5.10 FLASH ARRESTERS. During new construction and overhaul, the building yard or Naval shipyard will remove and store the ship’s flash arresters and replace them with flash arresters maintained especially for this purpose. The flash arresters are reinstalled just prior to normal underway operations, thus ensuring that flash arresters are functional in all respects. During the interim period, the temporary arresters are cleaned and tested annually in accordance with paragraph 223−5.2.2, and visually inspected semiannually for nonwetting and cleanliness. If faulty units are found, all are to be removed, cleaned and tested.

223−5.5.11 BATTERY WATERING. Due to low battery usage, cells will be relatively gas free and the electrolyte level will be low. Low temperatures below 18°C (65°F) will also contribute to low electrolyte level. During new construction, overhaul and extended availability periods DI water is added only when necessary to maintain the electrolyte level above the minimum level specified in the applicable service manual. Do not add water for any other reason. When additions are necessary, add sufficient amounts to raise the level no higher than that specified in the applicable battery service manual and as indicated by the electrolyte level indicator. No special charge is required. Standard watering procedures should not be followed until normal battery operations are resumed and six to seven additional equivalent cycles are accumulated and when the average pilot cell temperature is 18°C (65°F) or greater.

223−5.5.12 ELECTROLYTE ANALYSIS. In addition to the annual requirements of paragraph 223−5.5.5, an electrolyte analysis should be performed as follows:

a. When evaluation of individual cell voltage (ICV) and specific gravity data indicate a malfunction that cannot be explained by loose or corroded electrical connections, improper agitation, missing separator or similar problem.

b. When the air agitation system blower/motor reverses rotation, due to improper phasing of shore power, and draws electrolyte into system piping, or electrolyte is accidentally drawn into the system piping due to a line−up failure or due to compartmental pressure differentials.

c. Following the removal of a temporary low−pressure air supply connection to the battery air agitation system. These systems run the possibility of contaminating the battery with moisture pumped in from this outside source during extended shipyard stays.

223−5.5.13 TWO−OHM LOAD TEST. The two−ohm load test (paragraph 223−6.3.1.5) is done monthly and prior to each equalizing charge. As indicated by the test, inspect for loose or corroded ICV and fuse connections in the battery tank and at the ICV panel. In addition, the test can be done at any time to verify an ICV reading with regard to sensing circuit resistance. However, the test will detect high resistance (1.5 ohms or higher) at the cell terminal to bus bar interface only when the battery is on open circuit. This test is not required on installations having a digital voltmeter installed in the ICV panel.

SECTION 6.
BATTERY TROUBLES AND REMEDIES

223−6.1 GENERAL FAILURE AND TROUBLE INFORMATION

223−6.1.1 CAUSES OF FAILURE. Failure of a submarine main storage battery is usually attributable to age or cycling (working) and may be expected from the following conditions:

a. Disintegration of positive grid structure

b. Loss of active material from positive plates

c. Deterioration of negative active material

d. Severe internal short circuits.

There is no remedy for these conditions. Once they have occurred the battery should be replaced. Batteries installed in nuclear submarines are usually replaced due to age. Battery failure may be greatly accelerated by improper operation and maintenance. Therefore, conformance to this volume and the manufacturer's service manual is imperative to ensure the battery delivers maximum performance over its expected life.

223−6.1.2 ELIMINATION OF FAILED CELLS. Failed submarine battery cells are not usually replaced until the battery is replaced. Cells that fail prematurely are jumpered out of the battery circuit. A submarine battery can continue to provide satisfactory service even if several low cells are jumpered out. As the battery approaches end of life, some cells will become much lower in capacity than others, thus limiting battery capacity. Though indiscriminate jumpering out of cells is to be avoided, cells that are materially lower than the average and that significantly degrade battery capacity and performance should be jumpered out. Prior to jumpering out a cell, analyze its history to determine whether the problem can be remedied, that is, mechanical failure of the agitation system or an improper reading, faulty fuse or bad voltage lead. If the situation allows, advice from the Force Commander and battery manufacturer should be obtained prior to jumpering a cell out of the battery. When a cell is jumpered out, a note should be made in the Quarterly Battery Report with reasons for taking the action.

223−6.1.3 PRINCIPAL BATTERY TROUBLES. The principal battery troubles discussed in paragraphs 223−6.2 through 223−6.8 are:

a. Self-discharge, paragraph 223−6.2

b. Low capacity cells, paragraph 223−6.3

c. Sulfation, paragraph 223−6.4

d. Impurities in electrolyte, paragraph 223−6.5

e. Battery grounds, paragraph 223−6.6

f. Air agitation system malfunction, paragraph 223−6.8.

223−6.2 BATTERY SELF-DISCHARGE

223−6.2.1 SELF-DISCHARGE CAUSES. A lead acid battery always shows at least a low rate of decline in specific gravity when standing on open circuit. This drop in specific gravity is usually accompanied by a drop in battery capacity. Except for electrical self-discharge caused by internal short circuits, normal self-discharge, sometimes called local action, is chemical and electrochemical and is a characteristic of all lead acid batteries.

223−6.2.2 SELF-DISCHARGE (LOCAL ACTION) EFFECTS. The effects of chemical action of sulfuric acid on lead and its oxides and the electrochemical action of impurities in contact with lead, are described in sections 223−6.2.2.1 through 223−6.2.2.3.

223−6.2.2.1 Decrease in Electrolyte Specific Gravity. Cell specific gravity decreases approximately one-tenth of a point per day at 26.7° C (80° F) for the calcium grid cells.

223−6.2.2.2 Decrease in Battery Capacity. The reactions between active materials and the resulting drop in specific gravity causes a capacity loss when the battery stands on open circuit. The longer the stand time, the greater the loss. Since the drop in specific gravity is much less for calcium grid batteries, they can survive correspondingly longer open circuit periods.

223−6.2.2.3 Hydrogen Evolution. One by-product of the chemical reactions is hydrogen, which is produced in an amount proportional to the acid converted and is generally very small in comparison to equalizing charges. However, proper ventilation in accordance with Section 4 should be maintained.

223−6.2.3 FACTORS AFFECTING SELF-DISCHARGE. The rate of chemical self-discharge depends upon a number of factors, some of which include those described in the following paragraphs.

223−6.2.3.1 Time Period Since Last Charge. The rate of chemical self-discharge is most rapid immediately after charge and then decreases somewhat to a more or less constant value. For a battery that has been cycled enough to develop maximum performance, the capacity lost on open circuit increases with the length of stand.

223−6.2.3.2 Specific Gravity. The rate of chemical self-discharge increases with the specific gravity of the electrolyte.

223−6.2.3.3 Temperature of Electrolyte. The rate of chemical self-discharge increases with the electrolyte temperature. The rate of hydrogen evolution on stand increases in proportion to the rate of self-discharge and can be used to show the increase in self-discharge with temperature. Although the amounts of hydrogen evolved by different batteries vary greatly, hydrogen evolution increases tenfold with a temperature increase from 26.7° C to 54° C (80° F to 130° F).

223−6.2.3.4 Purity of Electrolyte. Chemical self-discharge is materially increased by even extremely small amounts of impurities; notably iron, nickel, chlorine, organic acids and copper. Due to the pronounced effects of even small amounts of impurities, extreme purity of the electrolyte is necessary for the best battery performance. See paragraphs 223−2.9.2.3 and 223−5.5.5 for the maximum allowable impurities in new and used electrolyte, respectively, and paragraphs 223−6.5.3 through 223−6.5.6 for methods of eliminating impurities.

223−6.2.4 MINIMIZING SELF-DISCHARGE AND HYDROGEN EVOLUTION ON STAND OR DISCHARGE. The hydrogen evolution on stand or discharge is proportional to the chemical self-discharge. Both increase with time since last charge (paragraph 223−6.2.3). The rate of increase can be kept to a minimum by closely observing the charging instructions (paragraphs 223−3.2 through 223−3.4.6) and maintaining the purity of electrolyte by care in watering (paragraphs 223−5.3.1 through 223−5.3.3). Make electrolyte analysis (paragraph 223−5.5.5) annually and whenever contamination is suspected.

223−6.2.4.1 Indication of Accelerated Self-discharge. A decline in the equalizing charge voltage usually indicates an increase in self-discharge. Accurate voltage readings are necessary to detect an actual decline (five volts or more). Whenever such a decline is observed, it is advisable to stop partial charges except when necessitated by high battery temperature or operating emergencies.

223−6.2.5 INTERNAL SHORT CIRCUIT. An internal short circuit (which gives rise to electrical self-discharging) is a metallic electrical conducting path within one cell between plates of opposite polarity. Such a conducting path discharges a cell just as if the plates were connected together by a conductor outside the cell. The rate of discharge will be equal to the potential difference between the points bridged by the path, divided by the resistance of the path, in accordance with Ohm's law.

223−6.2.5.1 Moss Short Circuit. The usual origin of a moss short circuit conducting path is the formation of a projection of sponge lead, starting from the negative plates and extending into the electrolyte sufficiently far to make contact with a part of the positive plates or positive terminal connector. This formation is termed a ”tree,” and the individual particles making up the tree are described as ”moss.” Hence, such an internal short circuit is commonly described as a moss short circuit. Depending on the battery design, protection against such a short circuit is provided by a coating of insulation at grid tops and terminal risers, extension of separators beyond plate edges, insertion of moss shields between plates and use of plate edge binding strips.

223−6.2.5.2 Sediment Short Circuit. A much less common source of internal short circuits results from the piling up of conducting sediment (dislodged active material) in the sediment space below the plates, until the height of the sediment is sufficient to make contact with the bottom of both the positive and negative plates. Adequate sediment space will prevent formation of such a short circuit.

223−6.2.5.3 Occurrence of Short Circuit. Internal short circuits normally occur only in cells approaching end of life or early in life where a defect, such as a separator having a crack or hole, is present. The accumulation of sediment and the formation of trees across the edges or tops of the plates may take several years to develop into a short circuit.

223−6.2.5.4 Symptoms. Failure of a cell to come up on charge when the rest of the battery is fully charged may be due to an internal short circuit. In a bad case, the cell may discharge itself at a rapid rate on open circuit stand or trickle-discharge. The cell voltage will be low on charge, discharge or open circuit and the cell may be hotter than the adjacent cells. The temperature of a shorted cell may be 5.6° C (10° F) (or more) above the average cell temperature, at any time. Specific gravity may be low in a shorted cell.

223−6.2.5.5 Confirmation. Having identified one or more suspected short-circuited cells by the symptoms previously described, use the following procedure for confirmation:

1. Trickle-discharge the battery for five hours at 10 amperes for GUPPY I Mod C, 15 amperes for GUPPY I Mod E and 20 amperes for TRIDENT; a shorted cell may be 0.1 volts or more below the average cell voltage.

2. Trickle-charge the battery at 25 amperes for Mod C, 35 amperes for Mod E, and 50 amperes for TRIDENT; a shorted cell may be 0.1 volts or more below the average cell voltage.

223−6.2.5.6 Corrective Action. Having performed the confirmation procedure, carefully reexamine the cell to ensure that none of the factors cited in paragraphs 223−6.3 through 223−6.5 are causing the symptoms or giving false confirmation. If no contrary indications are found, jumper the cell out of the circuit. If contrary indications are discovered, then conduct an equalizing charge according to paragraph 223−3.2.8 and the manufacturers technical manual. Continue to charge at the finishing rate until the designated pilot cells and switchboard voltages stabilize and cease to increase for two hours. Jumper the cell based on any of the following criteria:

a. During discharge the cell limits battery capacity below 80 percent

b. During emergency use the cell prematurely reaches low voltage

c. After an equalizing charge the corrected specific gravity or battery-corrected voltage is below the applicable battery specification.

223−6.2.6 JUMPERING CELLS. Normally in submarine battery installations, cells that fail prematurely are jumpered out of the battery circuit. Though indiscriminate jumpering out of cells is to be avoided, cells that are materially and consistently lower than average should be jumpered out. The capacity of the battery is computed using the time required for a cell to reach minimum individual cell voltage or for total battery voltage to decline to minimum final voltage. Thus, the maximum number of cells that can be jumpered out is not determined as a number such as four, five or six, but is dependent upon the ability of the battery to deliver 90 percent of rated capacity before falling below the minimum final cell voltage as specified for the rate on the curves and data for the installation.

223−6.2.6.1 Preparation. Before starting work to jumper out a cell, ensure that all hardware and tools required to jumper a cell from the battery type installed are available.

a. Particular attention in obtaining the proper fuse box support bracket is necessary since this piece is not always used at initial battery installation and, when it is used, may not be compatible with the jumper cable due to interference with the jumper cable bolt or surrounding bus bars. Brackets are not used when in-line fuses are installed.

b. Jumper cable assemblies ordered out of supply will have all hardware shown in Figure 223−26 attached or assembled. Nuts, bolts and washers will be lead-coated steel or stainless steel (316 stainless only). The locknut shown in Figure 223−26 is used only with stainless steel hardware. The 1.5 meter (m) [60 inch] cable assemblies are used to jumper end cells and crossover cells. The 0.75 m (30 inch) cable assemblies are used to jumper in-line cells. The 1.8 m (72 inch) cable assemblies are used on TRIDENT for crossover and end cells.

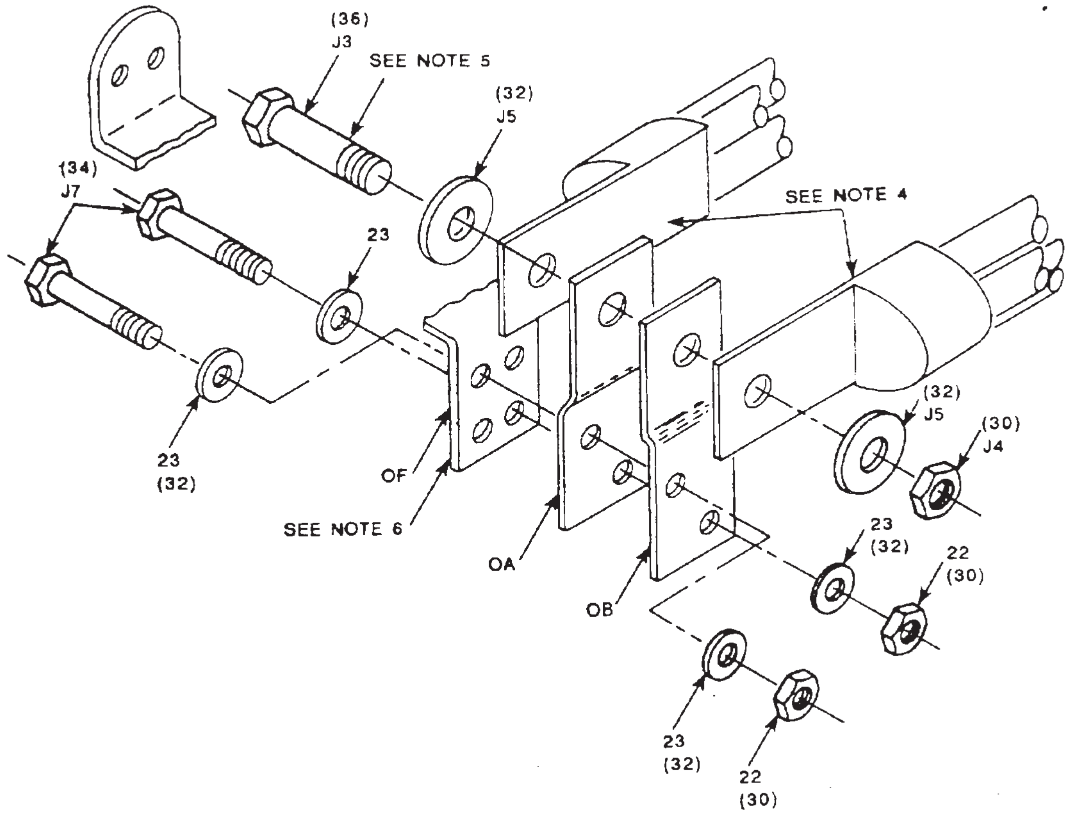


Figure 223–26. Jumper Cable Hardware

c. Examine cables for both electrical and mechanical condition. Determine location of cell to be jumpered. In rare cases two or more in-line cells may require jumpering or an obstruction may exist that will prevent the normal installation of a jumper cable assembly described in paragraph 223–6.2.6.3. The resulting installation will be unique and may require 1.5 m (60 inch) or 0.75 m (30 inch) cable assemblies, or both, connected in series to jump over or around defective cells and obstructions. For these special installations the arrangement of jumper cable hardware may differ from that shown in Figure 223–26 in two respects; the jumper cable lugs may be rotated 90° so as to be parallel to the cell terminal and, when connecting cable assemblies in series, four jumper cable lugs are bolted to one pair of contact pieces, which in turn are bolted (without the fuse box support) to a terminal of a cell being jumpered. The 20 millimeter (mm) by 102 mm (3/4 in. by four inch) bolt required is not normally supplied with jumper assemblies however, four bolts are supplied with replacement batteries. If four-inch bolts are not available, the series connection may be made with a standard three-inch bolt followed by insulating the connection point to prevent short circuits.

Using these special arrangements and using the terminals of defective cells, which are not grounded, as supports, any number of in-line cells may be jumpered using series-connected jumper cable assemblies. One fuse box support is required at each end of the series-connected jumper assemblies.

223−6.2.6.2 Precautions. Observe all safety precautions for working in battery well.

a. Ventilate battery while on open circuit.

b. Never work alone when jumpering out a cell.

c. Never repair a connection when current is flowing.

WARNING

> An accidental opening of the circuit when current is flowing can create an electric arc, resulting in personnel injury and damaged equipment.

d. All tools shall be insulated (paragraph 223−2.11.8). Exposed metallic surfaces on the insulated torque wrench should be wrapped with insulated tape, the wrench reversing switch however should not be covered.

e. Tools shall be shorter than the distance between positive and negative terminals, whenever practical.

223−6.2.6.3 Procedure. A cell is jumpered out of the battery circuit as follows:

1. To prevent delay, assemble all parts and tools and lay them out in an orderly manner. Insulate work area with rubber sheets to prevent accidental short circuits.

2. Place battery on open circuit and open disconnects in accordance with existing Engineering Department Operating Procedures. Attach WARNING tags to circuit breakers and control boards indicating work is being performed. Ensure that emergency lighting disconnect switch is open.

3. Remove fuses from each side of the cell to be jumpered and remove all intercell connectors on cell itself. However do not remove or secure the air agitation to the jumpered cell; normal air agitation should remain intact.

4. With fine-grained sandpaper (00) and light strokes, clean the contact surfaces of terminals and cell jumper contacts. Apply a coating of heavy mineral grease (VV−P−236 Petrolatum) to the clean surfaces and to all lead-plated terminal bolts, washers and nuts. Wipe off excess. Do not grease stainless steel hardware.

5. Connect one jumper at a time (to prevent having too many loose ends) and tighten with the specially insulated torque wrench as described in paragraph 223−2.11.8.

CAUTION

> The remaining loose end of the intercell connector should be placed on the insulated rubber sheets. Carefully observe end to prevent accidental contact with other cells or materials. The end should be secured to other cell terminal upon completion of first end connection.

Prevent excessive damage to lead plating on bolts, washers and nuts, and to lead plating on intercell connectors and terminals. Wipe off excess grease.

6. Position individual cell voltmeter fuse boxes removed from intercell connectors so that each fuse box is mounted on the fuse box support shown in Figure 223−26. One fuse box support is required at each

end of the jumper cable assembly. In-line fuses are mounted at these same locations, but without a support bracket.

7. Position cables to ensure minimum stress will be on battery terminals.

8. Protect cables from mechanical damage (that is, rubbing against overhead or against supports) that could damage the insulation and result in a low resistance ground.

9. Reinstall fuses removed during step 3.

10. Following Engineering Department operating procedures to put battery on bus.

11. Enter details in the battery record book.

223−6.2.6.4 Solid Jumpers. If the required jumper cable assemblies are not available, or present a safety hazard, or if their location causes interference within the battery well, solid jumpers fabricated from the same material (see ship class drawings), and with the same current-carrying capabilities as intercell connectors, may be used. At crossover locations, the conductor in contact with inside surfaces of the cell terminals must be silver-brazed to the conductor in contact with the outside surfaces of the cell terminals. The required 90 degree horizontal angles shall consist of overlapped bus pieces silver-brazed together. Excess material at the angle beyond a four-inch radius shall be removed. Nuts and bolts or rivets shall not be used to make this connection. Silver-brazing shall be in accordance with QQ−B−654, Brazing Alloys, Silver Grade 3, using brazing flux in accordance with O−F−499, Flux, Brazing (Silver Brazing Filler Metal, Low Melting Point) Insulation of solid jumpers shall be in accordance with paragraph 223−2.11.10. Contact surfaces need not be lead-plated. All exposed copper should be coated with petrolatum or silver-plated with Cool Amp Powder, which is commonly used to repair silver-plated switchboard bus bars. Cool Amp Powder (available from Cool Amp Company, Portland OR) will not silver-plate over lead coatings or steel; it works on copper-containing metals and is intended only as a repair material.

223−6.3 LOW CELLS

223−6.3.1 DEFINITION AND CAUSES. Low cells are the most common source of trouble encountered in battery operation. A low cell is one significantly below the average in voltage, specific gravity or capacity. This condition may be brought about by various causes such as poor connections, loss of active material, local action, short circuits, loss of electrolyte, hardened negatives, corroded positive grids, sulfation and impure electrolyte. It may be detected by progressive loss of capacity, low voltage on discharge, low specific gravity or comparatively high temperature. The specific gravity of low cells will usually be below that of other cells both on charge and discharge.

223−6.3.1.1 Detection. Where readings taken on any cell are significantly above or below the average for the entire battery, the cell should be carefully observed during future operation to detect any increased deviation from the average. Following detection of a below average end-of-charge voltage, the below average cell should be monitored along with and compared against the pilot cells. Voltage trends between the low cell and known good pilot cells should be compared for as long as voltage readings are below average.

223−6.3.1.2 Treatment. Proper treatment, if started in time, will assist in keeping conditions uniform. The following instructions should be carefully studied and the appropriate remedies applied.

223−6.3.1.3 External Inspection. A cell with a voltage more than 0.10 volts below the average cell voltage during an equalizing charge or 0.05 volts on open circuit should be given an external inspection for loose cell connections, loose or corroded individual cell voltmeter connections, and loose or corroded individual cell voltmeter fuse connection. The two-ohm load test (paragraph 223−6.3.1.5) will indicate approximately 0.10 volts if the ICV sensing circuit is the cause of the low voltage reading. High resistance between a cell connector and cell terminal causes excessive heating of the cell terminal during high rates of charge or discharge and may even result in fusing the terminal to the connector if not detected in time. Inspect plastisol terminal insulation boots, especially where they touch the terminals, for signs of discoloration and charring caused by heat.

223−6.3.1.4 Voltage at Cell Terminals. Loose terminal bolts cause poor contact and high resistance between the cell terminal and cell connector. Since the individual cell voltmeter leads and fuses are connected to the cell connectors, high resistance between a cell connector and a cell terminal will cause the cell voltage to read low on discharge and high on charge. When a cell shows this condition during a charge or discharge, the voltage at the cell terminals should be checked by means of a portable voltmeter that has first been compared directly with the ICV monitoring panel voltmeter at the panel to confirm that the panel meter is not the problem. If the voltage measured at the cell terminals with the portable voltmeter is significantly different than that measured by the panel meter, the trouble is probably due to a loose connection in the cell connector or in the individual cell voltmeter lead; if it is similar, the trouble is probably within the cell.

223−6.3.1.5 Two-Ohm Load Test. Loose connections of the individual cell voltmeter leads or fuse box will cause sensing circuit electrical resistance to increase and the individual cell voltmeter, due to its low input impedance, to read low on both charge and discharge. The individual cell voltmeter reading for a cell with loose connections will be erratic, as well as low, if the electrical resistance varies. In either case, check the connections by a visual inspection and measure the resistance of the voltmeter leads and connections by shunting the individual cell voltmeter with the two-ohm load test button on the ICV panel. This test circuit has been removed from installations using a digital voltmeter since these meters have a high input impedance. A step-by-step procedure is provided in MRC EL−18 Q−6. The following equation gives the desired resistance with an accuracy sufficient for the purpose:

$$R = 2\frac{V_1}{V_2} - 1$$

Where: R = cell voltmeter leads and connection

V_1 = voltmeter reading without the shunt

V_2 = voltmeter reading with the shunt.

Readings taken on cells showing normal voltage, as well as on a cell or cells with low voltage, allow any abnormal resistance of the leads and connections to be found readily. The shunting with the two-ohm resistance is done with the battery on trickle-discharge or open circuit. Any cell reading 1.0 volts or less while shunted, (V2), is an indication of an increasing sensing circuit resistance and is to be checked for loose connections. A reading of approximately 0.10 volts will indicate that the sensing circuit resistance is the cause of the low cell voltage readings. Particularly suspect, when a high resistance is found, are the voltmeter fuse rating (223−2.11.12) and fuse holders that are loose or corroded.

223−6.3.1.6 Other Inspections. A cell with a low charge voltage not caused by external resistance (paragraph 223−6.3.1.3) may be contaminated (paragraph 223−6.5) or may be internally shorted (paragraph 223−6.2.5). A cell with low voltage on discharge could, in some instance, be the result of a separator being installed in reverse, that is, the flat side of the separator is adjacent to the positive plate rather than the negative. The grooved sides of the separator would be against the negative plate instead of the positive. This electrolyte barrier at the surface of the positive plate would result in low voltage at end of discharge. In this case, the cell would be jumpered out of the circuit if it limited capacity below that needed for operation. Considering that voltage is influenced by temperature, cells with higher temperatures will display a lower voltage than the cooler, adjacent cells. A low voltage troubleshooting functional dependency diagram is shown in Figure 223−27.

223−6.3.2 LOW SPECIFIC GRAVITY. Operating tolerance for individual cells is 10 points (0.010 specific gravity) (see paragraph 223−2.10.3.2). It is estimated that the cell capacity at low rates drops four percent for each 10−point (0.010 specific gravity) drop in specific gravity. This estimate assumes that the volume of electrolyte remains constant. If, however, the lower specific gravity is present in a cell with a larger electrolyte volume, the actual drop in capacity will be less than four percent per 10 points.

223−6.3.2.1 Causes. For the causes of low specific gravity, see paragraph 223−6.4.4.1 and low specific gravity troubleshooting functional dependency diagram, Figure 223−28. In some instances, lead-calcium batteries show a loss of 10 to 20 points in specific gravity early in life; this loss does not appear to be recoverable and is not associated with corresponding loss of capacity.

223−6.3.2.2 Action. A cell with a corrected specific gravity lower than the operating limit at the end of an equalizing charge should have its specific gravities rechecked with an accurate hydrometer. If the specific gravity is still low, check the agitation flow rate by using the procedures presented in section 223−5.4.2. The readings on the previous equalizing charges should be consulted to see whether there has been a continuous decline or whether the previous readings have generally been satisfactory. If there has been continuous decline, particularly if there have been readings above the upper operating limit, the cell may be sulfated, shorted or excessively self-discharged. (See paragraph 223−6.4.4.1 for indication of sulfation, paragraph 223−6.2.5 for indication of internal short circuits and paragraph 223−6.4.4 for indication of excessive self-discharge.) If the previous readings have been satisfactory, the one low reading may be in error. To check, take specific gravity readings on the low cell at the end of normal charges and compare the readings with the pilot cell readings. If the end-of-normal-charge readings are above the previous equalizing charge readings, it may be assumed that the low reading was in error. If the end-of-normal-charge readings are lower than the previous equalizing charge reading, then it may be assumed that the low reading was correct.

223−6.3.3 LOW CAPACITY. Low capacity on discharge may be the result of the following conditions: cells not fully charged prior to the discharge; excessive self−discharge, usually affecting only low

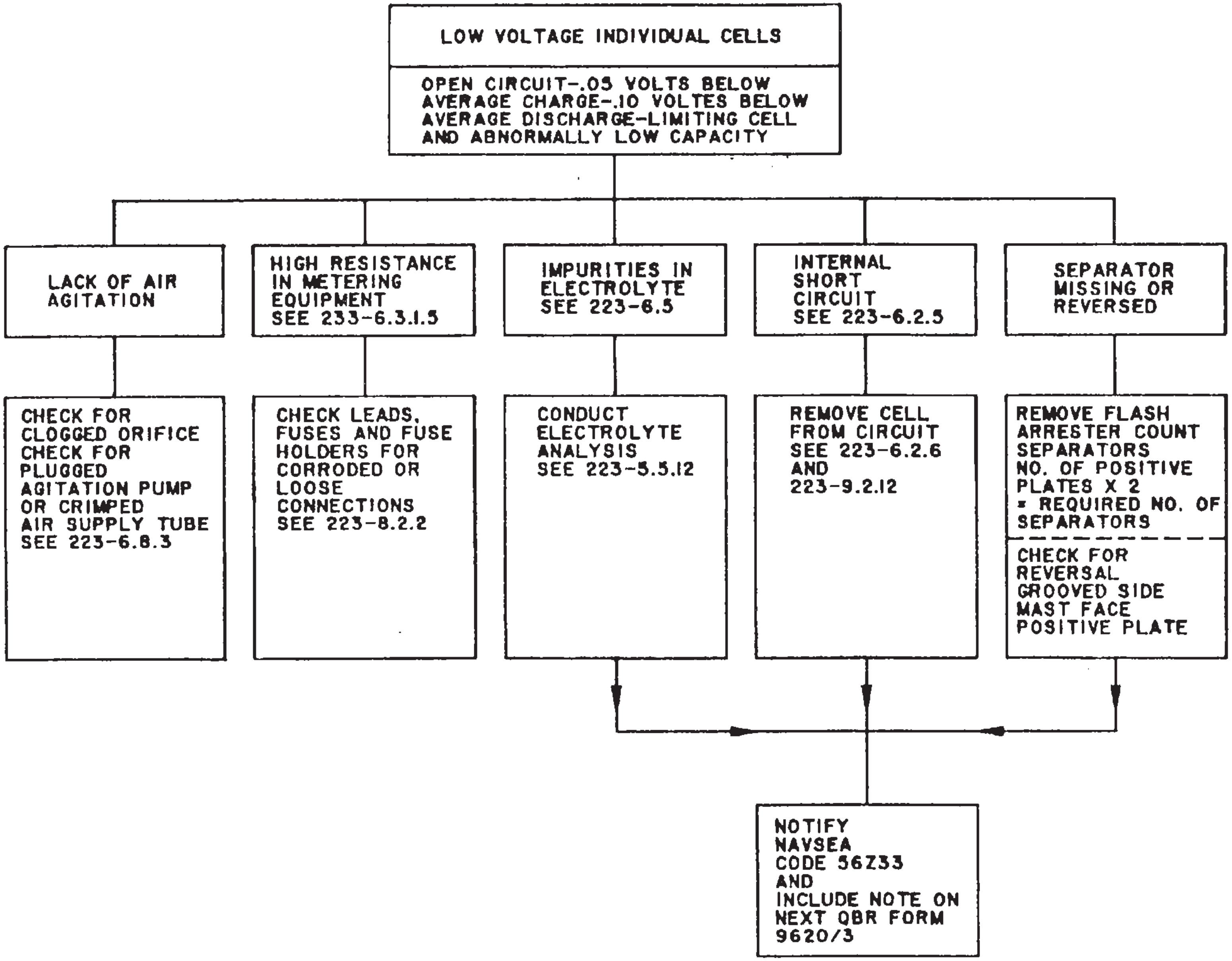


Figure 223–27. Low Voltage Troubleshooting Functional Dependency Diagram

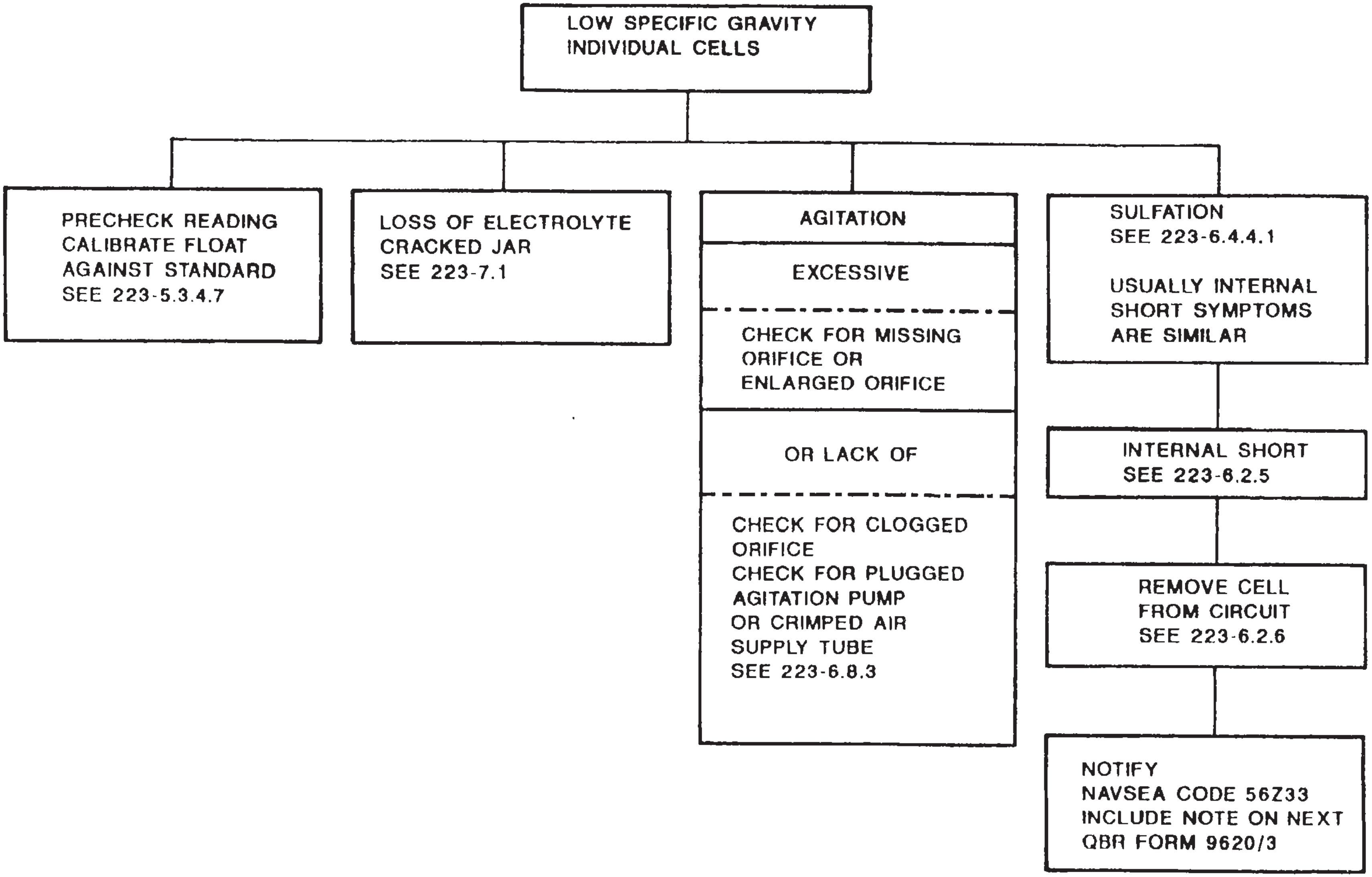


Figure 223−28. Low Specific Gravity Troubleshooting Functional Dependency Diagram rate discharges; or internal short circuit (paragraph 223−6.2.5). During test discharges, crimped or clogged air agitation tubes may also result in individual cell temperatures and specific gravities higher than battery average and cell voltages to limit battery capacity. These conditions can often be remedied. Other conditions, which cannot be remedied, include loss of active material as a result of age and overcharging as evidenced by discoloration of the electrolyte and excessive sediment (which may also lead to internal short circuits); and corrosion of the positive grid members as a result of age and cycling.

223−6.3.3.1 Positive Float. Lead-calcium batteries will lose some capacity if subjected to recurring inadvertent fluctuations between the charge and discharge mode of operation over an extended period. The capacity is maintained by the use of a low-rate trickle-discharge. Details are given in paragraph 223−3.5.14.

223−6.3.3.2 Action. In many cases, low capacity can be remedied by special charging and discharging. Any drop in capacity should be investigated and explained or corrective actions and remedies taken as required. Consult the battery service manual for specific actions and remedies regarding low capacity.

223−6.3.4 HIGH TEMPERATURE. Individual cells having temperatures 8.4° C (15° F) above the average of the battery should be inspected to determine the cause of the abnormal readings. If the cell is not shorted (see paragraph 223−6.2.5.4), high temperature may be caused by excessive resistance either at the contact surfaces of the intercell connectors and the cell terminals or, as a result of poor bonding, between the copper and lead of the terminal post. Within the first 10 cycles of battery life, an abnormally high temperature could be attributed to a missing separator, which would cause a massive short circuit. This type of failure is usually found prior to installation during the initial charge and cycle period in the battery shop. High individual cell temperature will normally result in the jumpering of the cell from the circuit unless attributable to loose or poor contact of the intercell. A high-temperature, troubleshooting functional dependency diagram is shown in Figure 223−29.

223−6.4 SULFATION

223−6.4.1 DEFINITION AND CAUSES. Sulfation is a condition in which some of the lead sulfate formed during discharge is fixated, that is, not reconverted to active material by a charge that would accomplish conversion in a normal, unsulfated cell. The fixation of sulfate, as described, is usually found only in the negative plates. Sulfate formed during discharge of the positive plates is much easier to convert and does not become fixed unless the cells are allowed to stand in the discharged condition for long periods. The reason for the change in lead sulfate properties that produces sulfation has not been well established. Battery records indicate that the condition develops whenever a battery has been incompletely charged for periods in excess of 30 days. Hence, it may be said that the usual cause of sulfation is the neglect, or the premature termination, of the equalizing charge (also see paragraph 223−6.5).

223−6.4.2 PREVENTION. The method for preventing sulfation is dictated by the cause. Compliance with charging instructions, paragraphs 223−3.2 through 223−3.4, is usually sufficient to prevent sulfation during the useful life of a battery. A large percentage of apparent battery failures can be attributed to sulfation. The

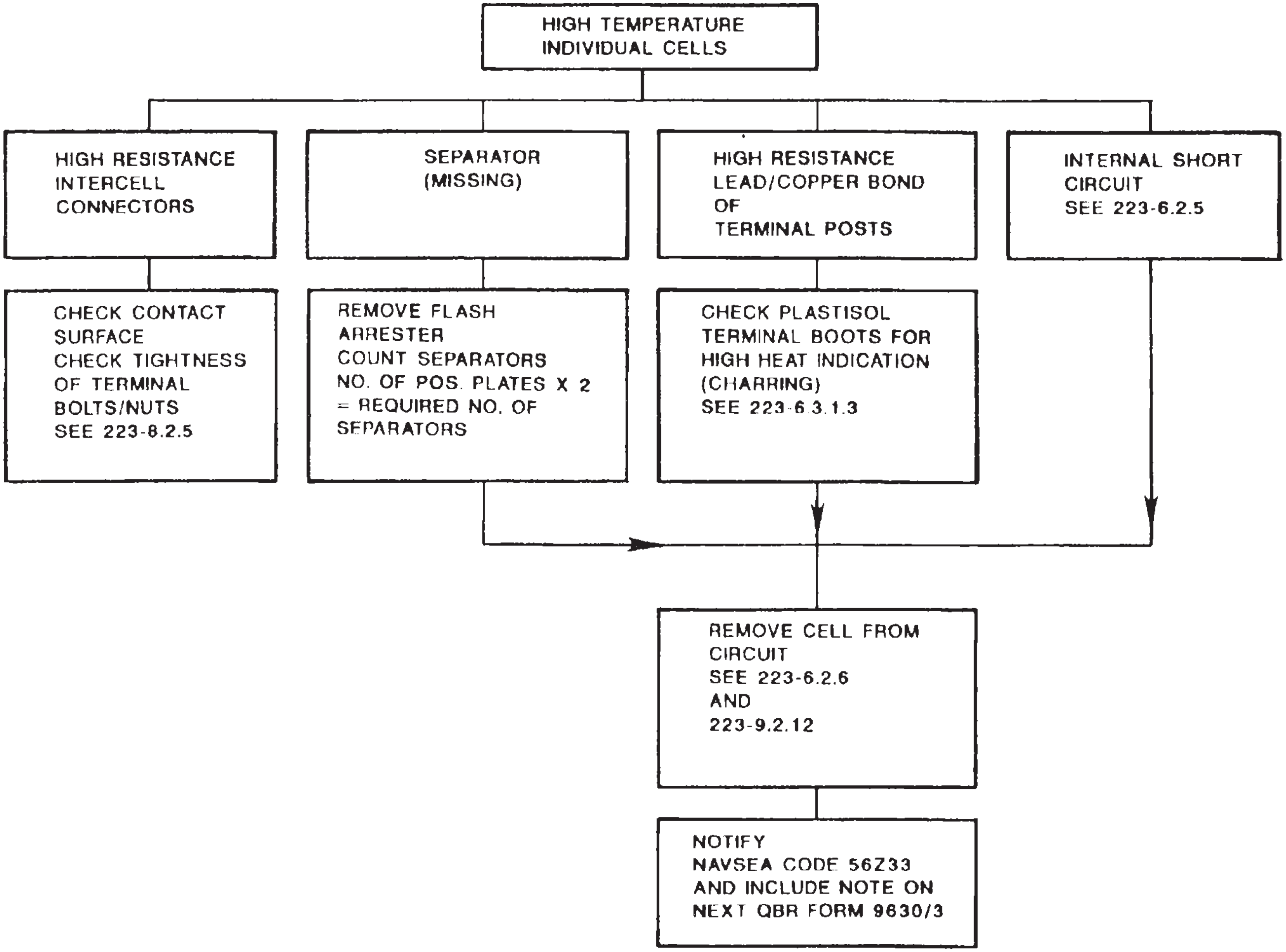


Figure 223−29. High-temperature, Troubleshooting Functional Dependency Diagram large investment in a battery installation requires that the instructions for preventing and remedying sulfation be followed. Accuracy of specific gravity and voltage measurements is vital. An actual decline in specific gravity and voltage may be overlooked if the readings on charges given at different times cannot be reliably compared. Since only small changes are involved in most instances, readings shall be as accurate as the instruments will allow. This practice will also avoid unnecessary treatment of sound batteries.

223−6.4.3 HARMFUL EFFECTS OF SULFATION. The harm done by sulfation is discussed in the paragraphs that follow:

a. Capacity. If sulfation is not corrected, battery capacity is reduced since, in effect, the battery is partly discharged. The reduction in capacity for a sulfated cell at high discharge rates is therefore greater than the decline in specific gravity would indicate since the discharged negative plate is less porous than a fully charged plate, causing the acid to diffuse into the plate less rapidly.

b. Overcharge. In order to charge sulfated cells fully, the charge must continue long after the positive plates have become fully charged. This prolonged charging reduces the life of the positive plates because active material is lost and positive grids are corroded.

c. Grid Structure. If the positive plates are sulfated because of a long stand in the discharged condition (paragraph 223−6.4.1), the positive grid members are stressed by the increase in plate volume and weight. If the battery has used about 50 percent of its normal life, the additional strain caused by sulfation may fracture the grids and thereby produce rapid disintegration of grid structure.

d. Cell Life. Cell life will be diminished in a sulfated cell even though treatment (as described in paragraph 223−6.4.5) restores full specific gravity and capacity. Extra charging will be required later to prevent sulfation recurrence. This additional charging will be detrimental to the positive plates, particularly to the grid structure. Normal life should not be expected from a sulfated cell that has had special treatment to restore full specific gravity and capacity.

223−6.4.4 DETECTION. Since it is very difficult to inspect the plates to determine their sulfate content, sulfation must be detected primarily by means of exterior signs. The most characteristic sign is an abnormally high cell voltage at the start of charge, followed by a below-average cell voltage at the end of charge. An end-of-charge decline in specific gravity (not due to actual loss or spillage of electrolyte from the cell) also indicates sulfation (paragraph 223−6.4.4).

223−6.4.4.1 Low Specific Gravity. A low specific gravity is not always a sign of sulfation. Although a sulfated cell will have a low specific gravity even after a charge that would bring a normal unsulfated cell up to full charge specific gravity, low specific gravity at the end of a charge is not always due to sulfation. It may be due to acid loss or to excessive self-discharge. The following will cause low specific gravity:

a. Electrolyte loss may result from spillage, particularly in rough weather. The amount lost may reduce specific gravity far below normal. Such loss can usually be confirmed by the presence of acid in the battery tank.

b. Careless handling of the hydrometer over a period of several years may result in a considerable loss of electrolyte from the pilot cells. This loss can usually be detected by comparing the specific gravity of the pilot cells with the specific gravity of cells adjacent to the pilot cells.

c. Electrolyte may be lost as a result of cracks in the jar liner. Such loss may be detected by an abnormal drop in electrolyte height and by persistent grounds that cannot be cleared by cleaning the cell tops.

d. The amount of electrolyte removed for chemical analysis must be replaced by pure electrolyte of the same specific gravity (paragraph 223−5.5.5).

e. A cell with excessive self-discharge will not come up in specific gravity as fast as a normal cell charged in series with it. In the normal cell, practically all of the charging current is used in producing the chemical reactions that restore the battery to a charged condition; in the other, only a part of the total current is used for chemical conversion, while the rest is wasted in self-discharge. The result is a low specific gravity in the self-discharging cell after the others have come up to normal. Since the overcharging on equalizing charges tends to bring up the low cells, the specific gravity of a cell suspected of excessive self-discharge should be tested at the end of normal charges as well as at the end of equalizing charges. If tests indicate that the lag between the low cell and the pilot cells is much greater on normal charges than on equalizing charges, excessive self-discharge is indicated. This may be caused by excessive chemical self-discharge (paragraph 223−6.2.1) or by an internal short circuit (paragraph 223−6.2.5).

f. Total or partial loss of air agitation will result in low specific gravity at the electrolyte levels where hydrometer readings are taken. Proper air agitation is indicated by a fluid spout height of 10 mm to 20 mm (1/2 to 3/4 inches) (paragraph 223−5.4.2) in GUPPY I Mod C batteries, or air bubbles viewed in the plastic tubing of GUPPY I Mod E and TRIDENT batteries.

223−6.4.4.2 Indications of Sulfation. Sulfation is indicated if a cell requires an excessively long charging time. This effect is because the conversion of fixated lead sulfate starts only when the cell is so nearly charged that it is gassing strongly, necessitating the use of a low charging rate. The effective charging current, which is the difference between the total charging current and the current used in generating gas, is usually so small that electrolyte specific gravity will increase at a very low rate, perhaps 0.001 specific gravity per hour. Sulfation is also indicated by the voltages on discharge and charge, as follows:

a. On discharge, a sulfated cell has a lower voltage than a normal cell even if both have the same specific gravity at the start of the discharge. For example, if a sulfated cell has the specific gravity raised to normal by the addition of acid, it will still have lower-than-normal voltage on discharge. This lower voltage results from the higher internal resistance of sulfated plates.

b. On charge, a sulfated cell will generally have a higher voltage than a normal cell when the charging current is high. Thus, it may be found that within 15 minutes after the start of a charge at the high initial rate, the voltage of a sulfated cell may be as high as 2.7. Normal cells in series with the sulfated cell may then have a voltage below 2.2 volts. As the charge progresses and the charging current is reduced, the voltage of the sulfated cell may drop below that of the normal cells and, when the normal cells have come up to maximum voltage at the finishing rate, the sulfated cells may have a voltage that, while still rising, is as much as 0.3 volts below normal.

223−6.4.5 TREATMENT. Sulfation can be remedied if treated in time. However, before deciding that treatment is necessary, ensure that the readings that indicate sulfation have been checked using accurate hydrometers and electrolyte-level indicators. Never use just a single reading, which may be high or low. Ensure that acid has not been lost from the cells, particularly when low specific gravities are experienced in outboard cells (which are difficult to inspect when watering and which may have been overfilled) (see paragraph 223−6.4.4.1). As sulfation may be caused by impure electrolyte, electrolyte samples should be analyzed prior to treatment. If excess impurities are found, the electrolyte should be renewed in accordance with the instructions in paragraph 223−6.5. If the following treatment fails to restore normal specific gravity, further treatment would not be indicated. The sulfation treatment procedure is as follows:

1. Continue equalizing charge until the requirements of section 223−3.2.8, paragraph b are met.
2. A stand of 12 to 24 hours, during which an accurate set of cell readings is taken.
3. Repeat steps 1 and 2.
4. Test discharge at the 3−hour rate. At the low-voltage limit, cell or battery (whichever occurs first), cut the rate to the 20−hour rate, and continue to the appropriate limiting voltages.
5. Repeat steps 1, 2 and 3.

Prior to initiation of charge, ensure that the temperature requirements of section 223−3.2.12 are met. Treatment success is measured by the gains in specific gravity after each of the equalizing charges. Since these gains are usually small (unless sulfation is abnormally extensive) it is vital that specific gravity readings be as accurate as possible.

223−6.5 IMPURITIES IN ELECTROLYTE

223−6.5.1 GENERAL. A decline in the specific gravity of a cell may be caused by impurities in the electrolyte. If this is the cause, it will probably be evidenced by very low charge voltage as well. Samples of electrolyte should be sent to a Navy laboratory or Intermediate Maintenance Activity (IMA) for chemical analysis to check compliance with paragraph 223−5.5.5. The more common impurities having harmful effects on battery performance are iron, nickel, copper and manganese. Other impurities are discussed in paragraphs 223−6.5.5 and 223−6.5.6.

223−6.5.2 CHLORINE. Chlorine as a common electrolyte impurity is discussed in paragraph 223−6.5.2.1. Entrance of chlorine into cells is known as salting. Chlorine usually enters a cell as a result of seawater flooding or the use of water from the ship's demineralized (DI) water supply contaminated with seawater. The chlorine is originally in the form of chloride. After mixing with the dilute sulfuric acid and exposure to the powerful oxidizing action of the positive action material, particularly during charge, part of the chloride is dissociated to free chlorine gas and is driven off in ventilating air. The rest of the dissociated chloride is perchlorate ion, which remains in solution; the maximum permissible level of chloride in solution is 120 ppm. Therefore, after a salted cell has been charged, it is found that nearly all the chloride present in the electrolyte is in the form of perchlorate ions, which are not detected by the silver nitrate test.

223−6.5.2.1 Harmful Effects of Chlorine. Chlorine causes self-discharge at both the positive and negative plates. Sulfation occurs at both plates. At the positive grid, this sulfated portion be−

comes lead dioxide during charge, converting the metal to lead dioxide. This weakens the grid and reduces its conductivity.

223−6.5.2.2 Indication of Salting. Chlorine in the battery exhaust gas is an indication of seawater in the battery. Chlorine has an intensely disagreeable, suffocating odor which causes a tickling sensation in the throat. A second indication of salting is an abnormally high electrolyte level accompanied by an extremely low specific gravity in the flooded cells.

223−6.5.2.3 Procedure When Salting is Suspected. When salting of a battery is evident, proceed as follows:

1. Secure air agitation system and, if possible, put battery on open circuit. If not possible, put battery on discharge at lowest possible current. Jumper out isolated salted cells. Under no circumstance put the battery on charge.

2. Operate battery ventilation system and air revitalization system at maximum capacity, ensuring all precautions are taken to prevent entry of battery gases into compartments. When it becomes necessary to recirculate battery gases throughout the ship, clear out chlorine by using carbon dioxide (CO_2) absorbent, which is also a chlorine absorbent.

3. Measure electrolyte level and specific gravity of all cells. Test those with a high level and low specific gravity (those that are probably salted) for chlorides as described in paragraph 223−6.5.2.4.

223−6.5.2.4 Rough Test for Chlorides in Electrolyte. To make a semiquantitative test for chlorides in electrolyte when the services of a qualified chemist are not available, proceed as follows:

1. Follow the procedure in paragraph 223−5.3.2.2, except place about 20 milliliters (ml) of the electrolyte to be tested in one test tube and about 20 ml of the 120 ppm comparison solution (paragraph 223−5.3.2.1) in the other. The chloride content of this comparison solution is equal to the maximum permissible chlorine content in used electrolyte. Add about two ml of silver nitrate solution to each of the two test tubes and shake, observing precautions set forth in paragraph 223−5.3.2.

2. Compare the milkiness of the two tubes. If the suspected sample is less milky than the comparison sample, it contains less than the specified limit of chlorine as chloride. This test does not indicate total chlorine content if seawater has been mixed with the electrolyte or if charging has resulted in conversion of chlorides to perchlorates. The silver nitrate test does not detect perchlorates. Samples taken within an hour after salting, when no charging or high-rate discharging has occurred, should serve as a reliable indication of the total chlorine content.

223−6.5.2.5 Preferred Treatment for Salted Cells. (Ship’s force often cannot use this method. See paragraph 223−6.5.2.6 for alternative treatment.) Since seawater has a much lower density than the cell electrolyte, it will remain as a layer on top of the electrolyte until mixed by charging at a rate sufficient to produce gassing, or by diffusion, ship motion and thermal convection currents. Prompt treatment of salting provides an excellent opportunity to remove all, or nearly all, the seawater before it mixes with and contaminates the electrolyte. The preferred treatment, if all the necessary facilities and materials are available, is as follows:

1. Throughout these steps, keep the battery or salted cells on open circuit or auxiliary load only, with full ventilation applied and the air agitation system secured.

2. Draw electrolyte from affected cells until the level is down to the plates. Use an acid pump having the inlet connected to a hose introduced into cell flash arrester opening. This procedure prevents mixing electrolyte with the salted layer at the top of the cell, and minimizes specific-gravity adjustments after chlorine has been eliminated.

3. Restore electrolyte to normal level by adding acid of the specific gravity present in the cell before salting.

4. Repeat steps 2 and 3. Take a sample of electrolyte from above the plates and check chloride concentration. If a qualified chemist is not available, use the method described in paragraph 223−6.5.2.4.

5. Repeat this procedure until the concentration of chloride is less than 0.012 percent.

6. When chloride concentration has been reduced below 120 ppm, restore battery air agitation and charge until the specific gravity has been constant for at least one hour. Apply full ventilation throughout the charge.

7. After the charge, a sample of electrolyte should be analyzed by a qualified chemist at the earliest opportunity (paragraph 223−5.5.5). If total chlorine, both as chloride and perchlorate, is less than 120 ppm, adjust electrolyte specific gravity to the specific gravity existing prior to salting and place the battery or cells in service. If, however, the analysis indicates an excess of chlorine, change the electrolyte.

8. If the electrolyte must be changed due to excessive chloride content, make the change when the cell is fully charged and electrolyte thoroughly mixed, if possible. Pump out as much of the impure electrolyte as possible and refill with pure electrolyte of approximately the same specific gravity. After each change, give the cell a mixing charge at the finishing rate for one hour and then have a sample of electrolyte analyzed for total chlorine. Continue until total chlorine content is 120 ppm or less by mass.

223−6.5.2.6 Modified De-salting Treatment When Acid is Not Available. Since submarines do not carry acid or spare electrolyte, the preferred method for de-salting (paragraph 223−6.5.2.5) can be carried out only on a ship that is at a base or tender where acid can be obtained. In such circumstances, the de-salting method to be used as follows:

1. When salting is first observed, proceed as per paragraph 223−6.5.2.3.

2. Draw electrolyte from affected cells down to near, but not below, plate level, following the instructions in paragraph 223−6.5.2.5.

3. If a base or tender can be reached before it is necessary to use the battery, except for auxiliary load, do not replace withdrawn electrolyte. Leave cells on open circuit or on as light a load as possible and, upon arrival at base or tender, complete the preferred method for de-salting in accordance with paragraph 223−6.5.2.5. If isolated cells have been salted, they should be jumpered out of the circuit.

4. If the battery must be restored to service before the ship can reach a base or tender and the salted cells cannot be jumpered out, restore electrolyte to normal level by adding DI water. The specific gravity of a fully charged cell will be lowered about eight points (0.008) for every 25 mm (one inch) of electrolyte withdrawn and replaced with DI water. To estimate the drop in specific gravity, take the difference between the electrolyte level before salting occurred and the electrolyte level after electrolyte is withdrawn. Cell capacity will be somewhat reduced because of the drop in specific gravity. Operate the battery as before it was salted, except use

full ventilation until no more chlorine gas is evolved. At the earliest opportunity, have electrolyte analyzed for total chlorine and, if in excess of 120 ppm, adjust electrolyte in accordance with paragraph 223−6.5.2.5.

223−6.5.2.7 Emergency Procedure When Battery Is Salted. In an emergency permitting no reduction in battery capacity, proceed as follows:

1. Secure air agitation system. Ventilate ship to outside atmosphere.
2. If flooded cells have an electrolyte level above normal, draw electrolyte from these cells to normal level. Restore air agitation system.
3. Put battery on charge at a rate sufficient to cause active gassing while maintaining a hydrogen concentration below three percent in battery exhaust. Take precautions to ensure that battery gases exhausted overboard are not recirculated back into the ship. Ventilate at maximum rate.
4. Continue charge until specific gravity has become constant and chlorine is no longer evolved from cells.
5. At first opportunity, have electrolyte analyzed by a qualified chemist; renew if necessary.

223−6.5.2.8 Procedure if Salting Occurs While Submerged. If salting occurs while submerged, secure agitation system and surface immediately if possible. If not possible, draw electrolyte from salted cells down to plate level and clear ship of chlorine by use of CO_2 absorbent or atmosphere control equipment.

223−6.5.3 IRON, NICKEL AND COPPER. Iron, nickel and copper electrolyte contamination usually occurs as loose metallic objects (for example, hardware parts, tools and personal possessions) enter into the cell or as a result of impurities in the DI water. Prevention, harmful effects and method of detecting contamination by these metals are discussed in paragraphs 223−6.5.3.1 through 223−6.5.3.4.

223−6.5.3.1 Preventing Contamination. Prevent contamination by observing the following procedures:

a. Purify all DI water by passing it through an ion exchanger (paragraph 223−1.9.12 before it enters a cell.

b. Always leave cell flash arrester and service caps in place unless removal is required for immediate maintenance. In other words, work on one cell at a time. Replace all cover hardware before moving on to the next cell.

c. Remove all loose metal objects, especially pens and pencils, from your person before entering the battery well.

223−6.5.3.2 Harmful Effects. Iron causes self-discharge at both the positive and negative plates and, if present in excessive quantities, can loosen the contact between the active material and the grids, causing loss of positive active material. Nickel depresses the negative plate charge voltage, which increases self-discharge and hydrogen evolution. Copper has an effect similar to nickel, but is not as harmful in equal concentrations.

223−6.5.3.3 Troubleshooting Impurities. Annual chemical analyses of electrolyte (paragraph 223−5.5.5) are required to detect the presence of excessive quantities of these metals. However, the presence of metallic impurities should always be suspected when the charge voltage of a cell is more than 0.05 volts below the average for the battery.

223−6.5.3.4 Treatment. Verify presence of impurities and obtain authorization to renew electrolyte in accordance with paragraph 223−5.5.5. This should be done as soon as possible after the contamination has been detected. Renewal is best performed as follows:

1. Give an equalizing charge.

2. Immediately after charge, withdraw as much electrolyte as possible and replace at once with pure electrolyte of the same specific gravity. To do this, pump out electrolyte, using electrolyte agitation tubes, until flow stops; then refill through service opening.

3. After first change in electrolyte, wait 12 to 24 hours, (preferably 24 hours) before changing again. To save time, do not cycle cells during this treatment unless a discharge test is to be taken to establish capacity. If a test discharge is to be taken, make next electrolyte change as soon after completion of discharge as practical and before the equalizing charge. The refilling electrolyte should always have the same specific gravity as that withdrawn.

4. Determine the minimum number of times to change electrolyte by comparing results of the chemical analysis with established impurity limits. Base the number of changes on the impurity showing the highest ratio between analysis and established limits, as follows:

Ratio of analysis to limit	Minimum changes
Less than 2	2
Less than 4	3
Less than 8	4

5. Repeat step 3 as often as necessary to make the minimum number of changes specified in step 4.

6. Analyze electrolyte 12 to 24 hours after making minimum number of electrolyte changes. If necessary, make additional changes until all impurities involved are down to one-half or less of established limits.

7. At end of process, give a thorough equalizing charge.

8. After operating for three to six months, analyze electrolyte to ensure impurities are below established limits.

223−6.5.4 MANGANESE. The source of manganese has not been established. It has been reported that such contamination comes from manganese found in hard rubber parts. However, such contamination is very rare and difficult to trace. Manganese appears to cause destruction of rubber separators. Even a few tenths of one ppm of manganese in the electrolyte have been destructive. Manganese may be removed by pumping out the electrolyte at the end of charge and refilling with pure electrolyte of the same specific gravity.

223−6.5.5 AMMONIUM NITRATES AND NITRITES. Ammonium nitrates and nitrites usually enter a cell as impurities in DI water (Table 223−7). These ions appear to become reduced at the negative plates to form ammonium ions, which remain in solution. Hence, the presence of ammonium ions may indicate that nitrates or nitrites have been added. The initial effect of nitrates and nitrites is to produce a marked increase in the rate of self-discharge of the negative plates. This increase in self-discharge is largely temporary, disappearing for the most part after the nitrates and nitrites are converted to ammonium ions. The same effect, initial increase in self-discharge, follows each time nitrates or nitrites are added. If nitrates are found in excess of 20 ppm in used electrolyte, analyze 30 days later. If the condition has persisted, renew the electrolyte.

223−6.5.6 OTHER CONTAMINANTS. Other impurities harmful to lead acid batteries include organic acids such as acetic and formic acids, dextrose, sucrose, and other agents that affect the positive plate both by increasing the rate of self-discharge and corroding the positive grids. These agents are oxidized to CO_2 and are usually very difficult to detect by analysis of electrolyte. Hence, no limits have been set for organic content in used electrolyte. With rigorous control of the organic content of the DI water (paragraph 223−2.9.2.3), no harm from those substances should occur. High organic content may be associated with a break in the DI water ion exchanger filter screen plate, which allows the resin to come through the hose. This should be investigated to ensure that used resin does not contaminate the electrolyte further by bringing metal ions into the electrolyte.

223−6.6 BATTERY GROUNDS AND LEAKAGE PATHS

223−6.6.1 DEFINITION. A battery ground is a leakage path for current extending from a conducting part of the ship's structure to a conductor in the battery. Current flow through these paths is indicated on the ground detector. Current may also leak along a path between cells without any connection to ground. Current flow through these paths is not indicated on the ground detector. No provision is made for their detection, but they may be as dangerous as grounds.

223−6.6.2 CAUSES. Leakage paths are usually formed by acid that is spilled on cell tops or by excessive moisture in the battery well. Cracked jar liners also are a source of grounds. Individual cell voltmeter leads occasionally become grounded and must always be considered in searching for grounds. In some nuclear submarines, grounds are the result of condensation forming in the battery well in cold seas. The battery becomes cool because it is not heavily worked, and battery well temperature may reach the dew point of the ventilation supply air, resulting in condensation. This can be avoided by heating the supply air before it enters the tank. A 4− to 6−kilowatt heater with a 66° C (150° F) safety cutoff switch installed in the supply duct effectively prevents condensation.

223−6.6.3 TYPES OF LEAKAGE PATHS. With any battery installation, leakage paths can be formed from the positive terminal of a cell through an electrolyte film on the cell top to the negative terminal. This leakage path does not register on ground detectors. A leakage path that does register on ground detectors can be formed from one terminal of a cell through the electrolyte film on the cell top and down a moist cell case to a conducting portion of the ship's structure.

223−6.6.3.1 Hazards Caused by Leakage Paths. Leakage paths such as those described in paragraphs 223−6.6.1 through 223−6.6.3 are hazardous for several reasons. The danger from any leakage path, whether to ground or from point to point in the battery, is greater for low resistance paths than for high resistance paths, and increases with the voltage difference between the ends of the path. Short leakage paths are likely to be of low resistance, and such paths between points that differ in potential by an appreciable fraction of the battery voltage are particularly hazardous. High voltage and low resistance both increase the leakage current.

a. A ground on a battery may furnish a return path for the current from another ground on any of the ship's power or lighting circuits. Under adverse conditions, this might cause a disastrous fire.

b. Battery grounds or leakage paths between cells may cause partial discharge of some cells or of the battery as a whole.

c. Grounds create the danger of electric shock if a person makes contact simultaneously with ground and a live conductor.

d. If the current is large enough, it gradually causes the insulation through and over which the current flows to deteriorate. This in turn results in lower resistance, increased current and still more rapid insulation deterioration. If not stopped in time, the deterioration may continue until leakage-current heat causes almost complete insulation breakdown. This will result in a short circuit of a part of the battery if the leakage path is from one point in the battery to another, or in a zero or nearly-zero resistance ground if the path extends to ground. Should a second zero resistance ground occur at another point in the battery, the result will be a short circuit of part of the battery, which can cause extensive damage.

When all leakage paths are of high resistance, however, leakage currents will be too small to cause significant insulation deterioration. The danger of shock as a consequence of simultaneous contact with ground and a live conductor will be small or nonexistent, and a short circuit will not result even if a single zero resistance should occur on the battery or on its connected circuits.

223−6.6.3.2 Troubleshooting Leakage Paths. The resistance of leakage paths that do not extend to ground cannot be measured. Valuable information on the resistance of grounds can, however, be obtained from a ground detector ohmmeter or voltmeter.

223−6.7 GENERAL PRINCIPLES OF GROUND RESISTANCE

223−6.7.1 CALCULATION OF GROUND RESISTANCE. The simplest ground resistance example is a battery isolated from all cables and equipment. If there is only a single 200,000 ohm ground on the battery, the resistance from the battery to ground is obviously 200,000 ohms; if there are two such grounds, the resistance to ground is 100,000 ohms since the two grounds are in parallel. Each additional ground on the battery will cause a further decrease in the resistance to ground. A battery will usually have a number of grounds rather than merely one. It is difficult to determine the number of grounds, or to measure the resistance of each ground individually, but it is readily possible to measure the combined resistance of all the grounds in parallel (R_g). If, for example, there are five grounds on a battery with resistance equal to R_a, R_b, R_c, R_d, and R_e, the Rg for the battery will be related to the resistances of the individual grounds as follows:

$$\frac{1}{R_g} = \frac{1}{R_a} + \frac{1}{R_b} + \frac{1}{R_c} + \frac{1}{R_d} + \frac{1}{R_e}$$

Normally a battery is not isolated from other circuits and equipment, but is used in combination with them. The term battery combination, as used here, will be considered to include all electrically-connected cable and equipment.

a. Consider the following example for a battery with ground resistance R_1; connecting cables, bus bars and switchgear with ground resistance R_2; and connected equipment with ground resistance R_3. The ground resistance, R_g, for this battery combination is related to R_1, R_2 and R_3 by the above equation for combining resistances in parallel:

$$\frac{1}{R_g} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

This is a basic equation for the study of ground resistance problems.

b. If R_2 and R_3 are both very large as compared to R_1, their reciprocals will be very small as compared to the other term, and can be neglected. The equation then becomes:

$$\frac{1}{R_g} = \frac{1}{R_1}$$

thus, the ground resistance R_g is equal to the battery ground resistance.

223−6.7.2 LIMITING VALUES OF GROUND RESISTANCE. Experience shows that grounds on the dc bus are usually in the battery. Ground resistance of the battery alone is normally several megohms and should be maintained as high as possible. If ground resistance of the battery alone is less than 50,000 ohms, charging is not permitted. If ground resistance of the battery alone is less than 100,000 ohms, only emergency charging is permitted (paragraph 223−3.4.5.1). Normal battery operations are permitted when the ground resistance of the battery alone is above 100,000 ohms but below normal values. The cause of any reduction in battery ground resistance which impacts the dc bus ground resistance should be identified and corrected. Other sources of reduced dc bus ground resistance are connected equipment (paragraph 223−6.7.3) and lighting or auxiliary power circuits (paragraph 223−6.7.4).

223−6.7.3 CONNECTED EQUIPMENT GROUND RESISTANCE. The ground resistance for any equipment (for example, motors, generators and control cubicles) that forms a part of a battery combination is usually so high that it need not be taken into account. However, if the ground resistance of equipment drops to a value comparable to that of the other items in the combination, it will cause the ground resistance for the combination to be materially lower than if the ground resistance of the equipment were high.

223−6.7.4 LIGHTING EMERGENCY LIGHTING, AND AUXILIARY POWER CIRCUIT GROUND RESISTANCE. The lighting, emergency lighting and auxiliary power circuits introduce additional factors that may require consideration. These circuits may not be disconnected from a battery by opening its battery circuit breakers, but normally have a ground resistance so high that it makes little difference whether they are connected or not. If, however, the ground resistance is found to be less than 100,000 ohms for a battery isolated by opening its circuit breakers, the lighting and auxiliary power loads on the battery should be shifted to another power source. The ground resistance should then be measured on the battery when it is disconnected from these circuits to determine whether the low value of ground resistance observed before was caused by grounds on the battery or by grounds on one of the circuits.

WARNING

> Ground resistance meters should never be used with personnel inside the battery tank due to the possibility of electrical shock.

223−6.7.5 GROUND RESISTANCE METERS. Most submarines have a ground detector ohmmeter that measures the resistance to ground (the R_g of paragraph 223−6.7.1) directly in ohms. These instruments should be used in accordance with the instruction manual directions. The small number of submarines without the direct reading ground detector ohmmeters have permanently installed ground detector voltmeters. The resistance to ground can be calculated from the ground detector voltmeter readings in accordance with the directions in the propulsion instruction manual.

223−6.7.6 LOCATING GROUNDS BY VOLTMETER READINGS. The following procedure is to be used in locating grounds by the use of voltmeter readings:

1. If the resistance to ground measures less than 100,000 ohms for a battery alone (battery isolated from propulsion, auxiliary power, and lighting and emergency circuits by opening disconnect switches), the next step is to locate and clear the grounds.

2. If there is only a single ground on the battery, its position can be found as follows:

    a. Measure V_p (the voltage between ground and the positive end of the battery) and V_n (the voltage between ground and the negative end of the battery). These measurements can be made on some submarines by using the individual cell voltmeter, on other submarines by using the scanner voltmeter, and on all submarines by using a portable voltmeter. Use the equation for fraction of battery voltage included between ground and (+) terminal:

$$\frac{V_p}{V_p - V_n}$$

For example, if $V_p = 120$ volts and $V_n = -30$ volts, then $V_p - V_n = 120 - (-30) = 150$ and the ground will be at 120/150 or 80 percent of the way from the positive to the negative end of the battery, hence, at about cell number 100 of a 126 cell battery.

    b. An alternative procedure that can be used on some submarines is to employ the voltmeter (paragraph 223−1.9.1) to measure the voltage from ground to each of the intercell connectors on the battery. If there is only a single ground on the battery, it will be very close to the intercell connector which gives the smallest voltage reading to ground.

3. Unfortunately, a battery is more likely to have several grounds than to have only one. The steps described in paragraph 223−6.7.7 should be taken. If one ground has a much lower resistance than any of the others, the tests given above fix a position close to the low resistance ground. If, however, there are several grounds with resistances of similar magnitude, there may or may not be a ground near the position indicated by the test.

223−6.7.7 CLEARING GROUNDS. Clearing battery grounds is usually more a matter of hard work in the battery tank than analyzing ground detector readings. When these show that the resistance from a battery to ground is less than 100,000 ohms the following procedure is recommended:

1. Break battery clear from all connected circuits not previously opened, by pulling the battery disconnect switches (paragraph 223−6.7.4). Make another measurement of ground resistance. If it is below 100,000 ohms for the battery alone, the ground is definitely in the battery.

2. If ground resistance still remains low despite the preceding operations, estimate the position of ground by the method described in paragraph 223−6.7.6. Look first near the position indicated. Remember, however, that the ground may be elsewhere.

3. Examine individual cell voltmeter leads and fuse clips on cell connectors for evidence of corrosion and moisture grounds. Disconnect individual cell voltmeter leads from suspected cells and test again.

4. If the foregoing proves ineffective, examine the tops and exposed parts of jars for evidence of acid streaks, leakage of acid through sealing compound, terminal post holes or other openings in the cover. Wipe off cell tops and exposed parts of jars with a rag dipped in a baking soda solution containing no more than 30 grams/liter of baking soda, followed by one dampened with DI water (paragraph 223−5.5.1) and test again.

5. If the ground persists, take off intercell connectors at point under suspicion or at center cell. Measure resistance to ground of each section (paragraph 223−6.7.8). Keep in mind that each of the two sections in parallel must have a resistance well over 200,000 ohms if their combined resistance in parallel is to exceed 100,000 ohms. If, for example, one has a resistance of 180,000 ohms and the other 200,000 ohms, the combined resistance is 94,740 ohms. Continue to clear each section, subdividing the battery further, if necessary, until the combined resistance of any two sections is greater than 100,000 ohms. If a single-cell ground cannot be cleared by disconnecting the cell from the battery and removing the voltmeter leads, a leak between cell and ground is indicated. If no acid can be observed on the cell top and the exposed portion of the jar, the ground is probably caused by a leaky jar.

223−6.7.8 GROUND RESISTANCE OF A BATTERY SECTION. When a battery is split into two or more sections by removing intercell connectors, the ground detector ohmmeter cannot be used to measure the insulation resistance to ground from any of the sections.

a. Use a portable voltmeter with a low input impedance to measure V_b and V_n voltages from ground to the positive and negative ends of the battery section, respectively. If a high impedance digital voltmeter is used, the first value read on the meter immediately after probe contact should be used in all calculations.

b. Compute the insulation resistance to ground, R_g, for battery section by the following equation:

$$R_g = R_v \left[\left(\frac{E}{V_p - V_n} \right) -1 \right]$$

Where: R_g = insulation resistance to ground for battery section

R_v = internal resistance of voltmeter used to measure V_p and V_n (ohms per volt times full scale range in volts)

E = voltage between positive and negative ends of battery section

V_p = positive terminal to ground voltage

V_n = negative terminal to ground voltage.

Note that the internal voltmeter resistance for portable voltmeters with several different scales has a different value for each scale. Always ensure that the value of R_v used in the above equation corresponds to the scale in use.

Example: Suppose the sensitivity of the voltmeter is 20 kilo−ohms/volt, and the meter is set to the 100V scale, then:

$$R_v = (20\text{ kilo−ohms/V})(100\text{V})$$
$$= 2.0\text{ megohms}$$

Using the above equation for R_g, and given the following values:

E = 250V V_p = 51V

V_n = −49V

Then:

$$R_g = (2.0\text{ megohms}) \left[\frac{250}{51\text{V}- (-49\text{V})} -1 \right]$$
$$= (2.0\text{ megohms})[2.5\text{V} - 1]$$
$$= 3.0\text{ megohms}$$

Note that when measurements are made to the ends of a section of a battery that is disconnected from all other sources of potential, V_p is always positive, V_n is always negative, and $V_p - V_n$ is numerically greater than either V_p or V_n, being numerically equal to the sum of the voltage readings (without regard to sign) taken at the two ends of the section.

223−6.7.9 GROUND RESISTANCE AND SAFETY. The greater the resistance to ground, the less the danger of electric shock if a person simultaneously contacts a ground and a live conductor. For this reason, every effort should be made to keep the ground resistance as high as possible. In addition, ground resistance measurements should be made before performing any work that involves touching a cell terminal. If the work involves disconnecting cells, be especially careful to insulate all parts of the body from ground by using a rubber sheet over parts of the ship's structure with which contact might be made. In this way, even if the battery should accidentally be grounded during the working period, it will not be likely that a person will simultaneously contact the live terminal and ground. Do not use plywood in lieu of a rubber sheet.

223−6.7.10 ELECTROLYTE OVERFLOW. An electrolyte overflow troubleshooting dependency diagram is shown in Figure 223−30. A large decrease in ground resistance may result from electrolyte overflow from a cell or cells. The most common cause is accidental overwatering prior to the start of a charge. If not detected and corrected, electrolyte may overflow during the gassing phase of the charge. (If overwatering is discovered prior to the start of charge, remove the excess electrolyte with a syringe, lowering to the average level of the pilot cells. If possible, retain this electrolyte in a clean container labeled with the cell number and use it instead of water to replace electrolyte in the cell as the level decreases through normal operation.) The same procedure applies if overwatering is not discovered until after the charge has been started and the cell actually overflows.

223−6.7.10.1 During Cell Reversal. Infrequently overflow may occur if a cell has been overdischarged and allowed to remain in a reversed state. In this case, on the following chargeback, observe individual cell voltage. If voltage upon start of charge rises to above 2.80 volts, take immediate action to prevent excessive gassing and height increase. If this condition is observed, reduce charging rate to maintain voltage of the cell at 2.80 volts or lower. Complete the charge using this cell as a guide to charging rate. Normally the cell will return to the average of the remaining cells; however, maintain it as a pilot cell on the next several charges. If a cell has been in a reversed condition for an extended period, it may be necessary to jumper the cell from the circuit if charging characteristics do not return to the battery average.

223−6.8 ELECTROLYTE AIR AGITATION SYSTEM MALFUNCTION

223−6.8.1 ELECTROLYTE STRATIFICATION. A prime cause of premature failure of individual cells on nuclear submarines is the loss of proper air agitation. When electrolyte circulation in a cell is stopped or reduced, the free electrolyte within the cell stratifies, that is, the heavier acid settles to the bottom of the cell, replacing any weak electrolyte of lower specific gravity. Stratification can occur during either low-rate trickle-discharges, normal nongassing charges or the nongassing portion of any equalizing charge. Since these modes of operation account for approximately 95 percent of the cycle-time for nuclear submarines, there is ample opportunity for stratification to affect the performance and life of any cell deprived of electrolyte circulation. A cell with stratified

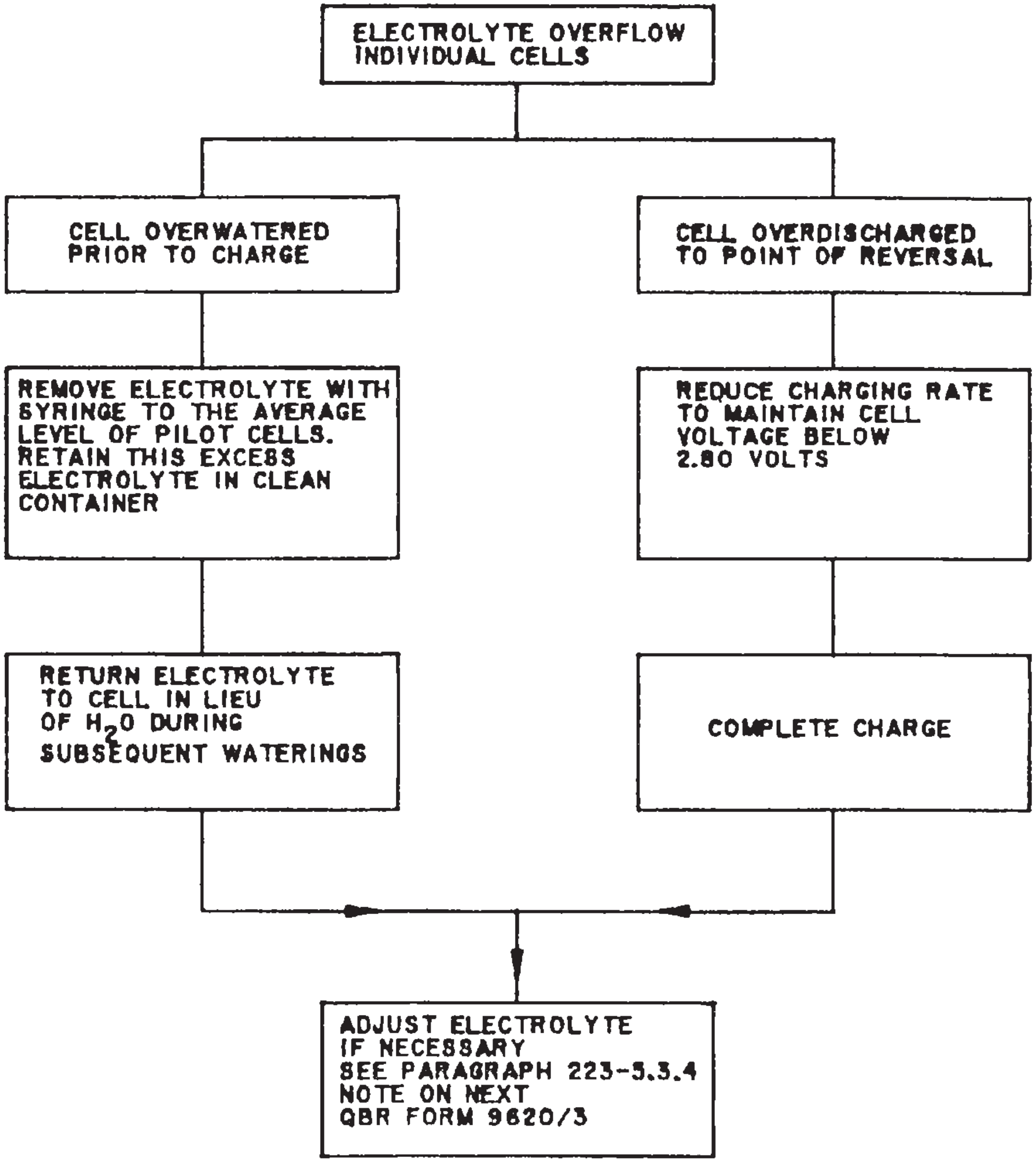


Figure 223–30. Electrolyte Overflow Troubleshooting Dependency Diagram

electrolyte initially performs as if it were only partially charged because the upper halves of the plates are deprived of electrolyte as the lower halves become sulfated. If electrolyte circulation by proper air agitation within the cell is not resumed, the sulfate crystals grow larger, becoming more difficult to remove (paragraph 223−6.4.5); the resulting cell damage may become permanent.

223−6.8.2 MALFUNCTION INDICATIONS. It is extremely important that the specific gravity readings of each cell be carefully analyzed right after they are taken each month.

a. If the specific gravity of any cell is 10 points (0.010) or more below the average reading of the other cells, the air agitation system for that cell may not be functioning properly.

b. After completing the gassing portion of a charge, a less-than-average specific gravity reading for a cell that has habitually been below the average specific gravity reading may indicate that the air agitation system in that cell is not functioning properly.

When either condition occurs, immediately conduct an airflow check on the suspect cell by removing the dome and visually checking the agitation flow. Do not check by listening over the cell covers for the gurgle of active agitation. The pumps can gurgle quite well while pumping negligible amounts of electrolyte or no electrolyte at all. The only positive check is to remove the flash arrester and actually observe the airlift pump discharge port to see whether the pump is functioning properly. The flow of electrolyte out of the pump discharge should be a fluid spout 10 mm to 20 mm (1/2 to 3/4 inches) in height for GUPPY I Mod C. For TRIDENT, GUPPY I Mod E and DOLPHIN batteries, proper flow is verified per procedures in section 223−5.4.3.

223−6.8.3 CLOGGED OR PINCHED AIR SUPPLY TUBE. Air agitation system malfunctions caused by a clogged or pinched air supply tube are discussed in paragraphs 223−6.8.3.1 through 223−6.8.3.7.

223−6.8.3.1 Clogging. Calcium grid battery airlift pumps are susceptible to clogging by calcium sulfate deposited at the bottom of the air supply tube. Routine maintenance described in paragraph 223−5.4.3.1 will prevent such clogging. Oil or oil vapor in the air accelerates calcium sulfate buildup (paragraph 223−5.4.3.1). During routine maintenance, if an air supply tube is found to be clogged, inspect the entire filtering system that removes oil and oil vapor from the air agitation system and replace the air supply tube. Do not clean and reuse a clogged tube.

223−6.8.3.2 Pinching. Pinching of the air supply tube usually occurs in an area 10 mm to 25 mm (about 1/2 to one inch) from the top of the tube. If the restricting force remains in effect for several hours or more, the polyethylene tube becomes permanently deformed. The air supply tube is usually pinched by excessive tightening of the coupling nut. This, in turn, depresses the soft rubber sealing gasket through which the tube passes. The forces produced are transmitted to the outer wall of the air supply tube, causing the pinching action. The coupling nut (Figure 223−31 and Figure 223−32) should always be only handtight. Under no circumstances should a wrench be used.

223−6.8.3.3 Corrective Action. When the air agitation system for a cell is not functioning properly, the checks described in paragraph 223−6.8.3.4 should be made to isolate and correct the defect.

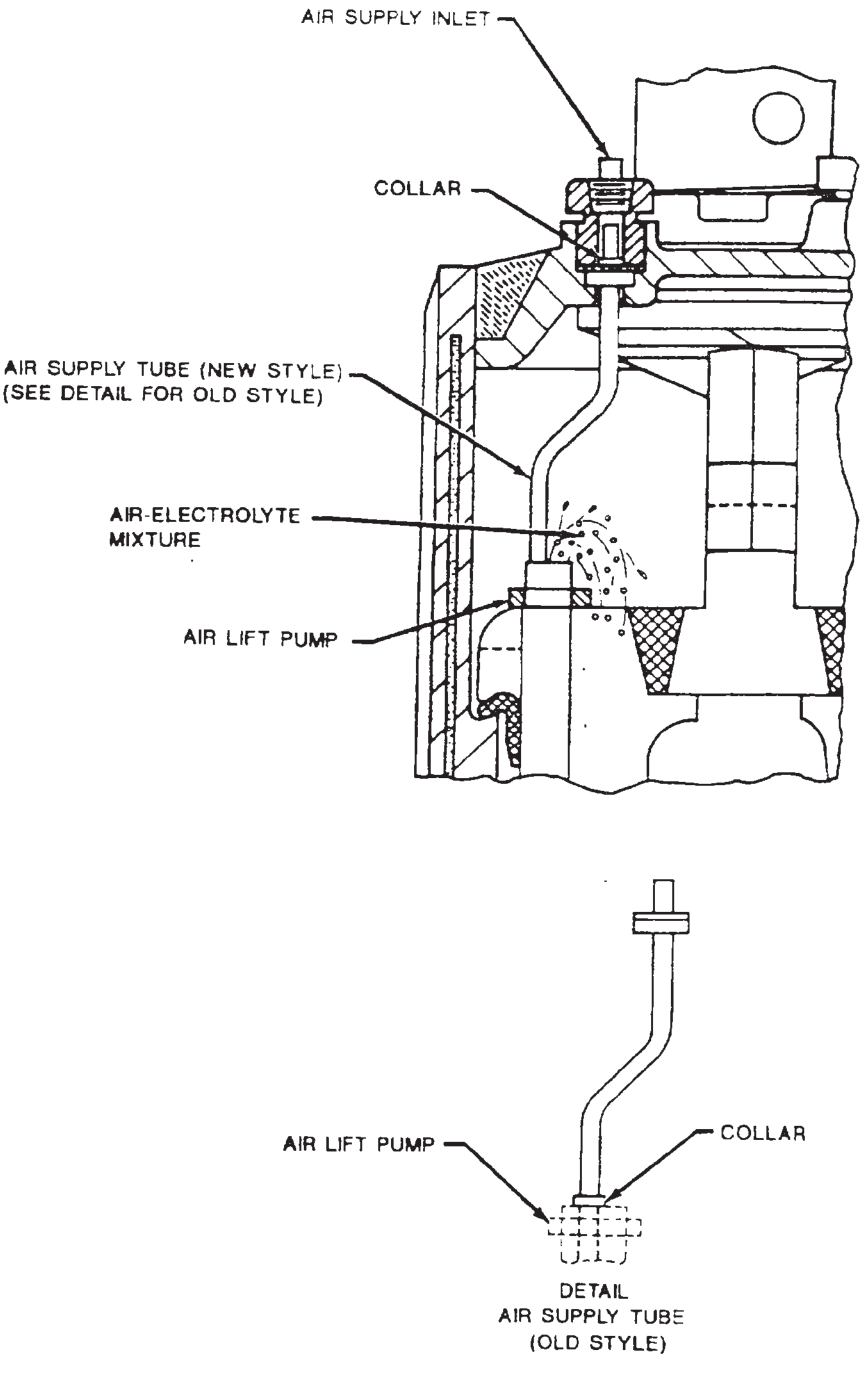


Figure 223−31. Air Agitation View for GUPPY I Mod C Cell

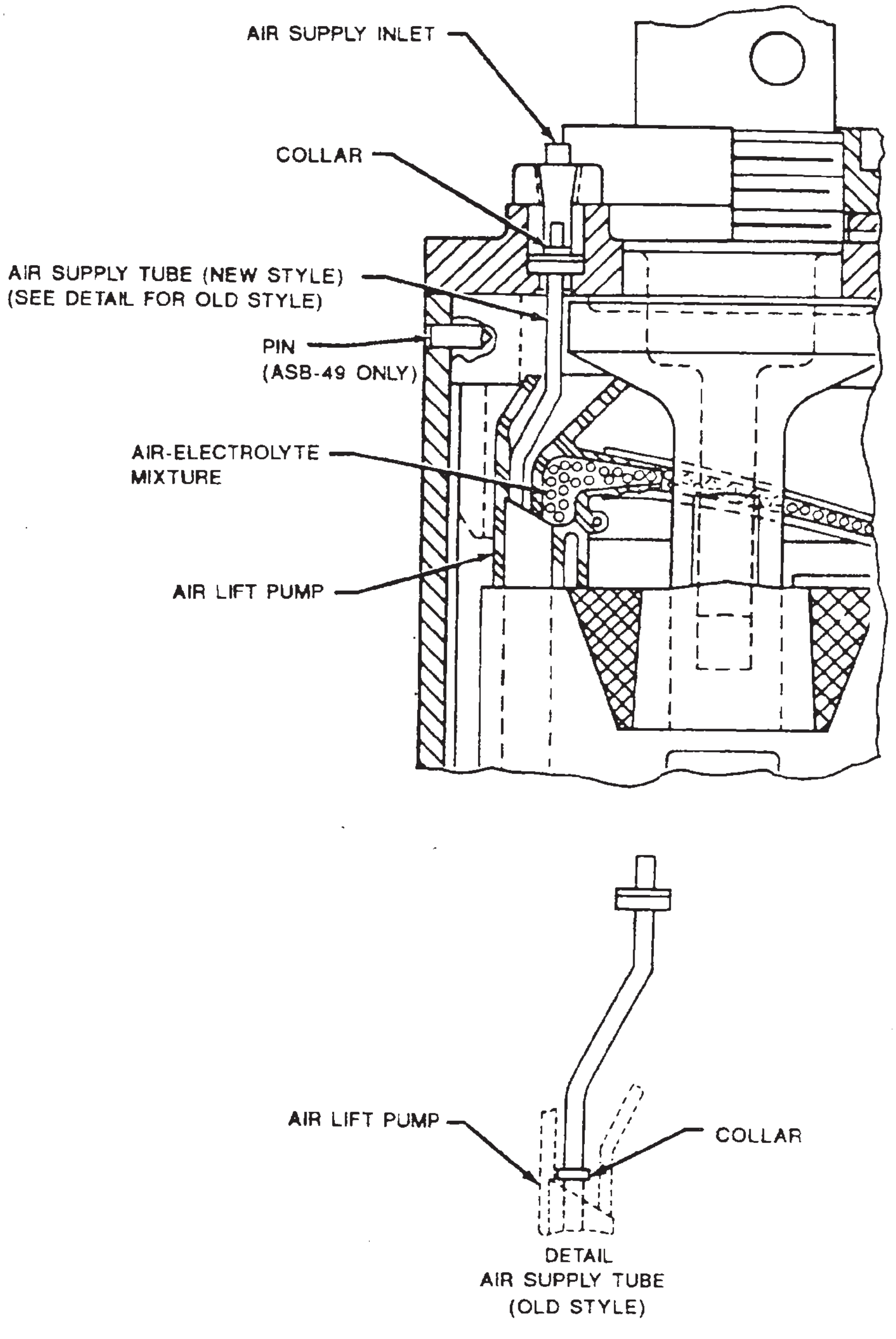


Figure 223−32. Air Agitation View for GUPPY I Mod E and PDX-57 Cells

223−6.8.3.4 System Checkout. Ensure that the system air supply source is operating and that the air supply gauge indicates airflow of at least 107 liters per minute (3.78 ft^3/min) for a 126−cell system. Airflow decreases 0.85 liter per minute (0.03 ft^3/min) for each airlift pump not in use (jumpered or removed cells). If airflow is out of balance, correct the flow and reinspect air agitation in the cell as directed in paragraph 223−6.8.2.

a. Check agitation in cell again after carefully removing orifice and blowing into the female coupling air supply line to the cell. If no effect is noted at top of air lift tube, the trouble lies within the cell and air supply tube. If agitation is observed, the problem is probably attributable to the orifice or airflow distribution of the system.

b. Check in-line air filter, paying particular attention to filter gasket alignment. Replace gasket if any damage is noted.

c. Check air headers and fittings in battery tank for any pipes, flanges, or couplings which are loose, ruptured, cracked or misaligned.

d. Check throttling orifice, located where the female coupling hose nipple is attached to the air supply header. Ensure the plastic throttling orifice is free to drop out of the female hose coupling. Inspect orifice and replace if clogged or crushed. Do not attempt to repair or enlarge the opening, its dimension is critical to system operation. Orifices must be present and correctly positioned; otherwise the self-equalizing feature will not be fully operative. Three missing orifices can cause poor performance in more than half of a 126−cell system, and six missing orifices will cause total ineffectiveness. Personnel can sometimes detect missing orifices by moving slowly along the cells in the battery tank while listening for unusually active cell agitation, since a missing orifice will cause excessive bubbling and splashing. This is a rough method of narrowing down defects; however, it has proven effective.

e. Check air supply hoses from headers to cell tops for cracks and kinks.

WARNING

> Remove and replace the air supply tube cautiously, since the tube and parts have been in contact with electrolyte. Protect against electrolyte contact by wearing rubber gloves and acid-proof glasses.

223−6.8.3.5 Air Supply Tube. To remove and replace the air supply tube, see Figure 223−31 or Figure 223−32 first, then continue as follows:

1. Disconnect agitation by removing female coupling hose nipple from male union at air supply header. Do not permit throttling orifice to be lost as it falls free from the female coupling when the disconnect is made.

2. Remove black coupling nut from cover agitation opening.

3. Pull white polyethylene air supply tube out of cell through cover agitation opening. The coupling washer and coupling seal gasket will remain on the air supply tube when it is removed from cell. Save the coupling seal gasket and coupling washer for reinstallation.

4. Discard the air supply tube if it is plugged or pinched.

5. Reinstall coupling seal gasket and coupling washer. Apply a thin coating of a silicone grease MIL−S−8660, before installation to prevent leaks.

On TRIDENT batteries this step is done prior to inserting tube.

6. Insert a new air supply tube through cover agitation opening. On GUPPY I Mod C installations, locate the top of airlift pump barrel (black plastic figure-eight tube opening) through flash arrester opening of cover and insert end of air supply tube into smallest opening of airlift pump barrel.

Continue pushing air supply tube into airlift pump barrel until collar is seated. GUPPY I Mod E and TRIDENT have an installed guide that directs the tube to the proper opening.

7. Reinstall coupling nut handtight. Never use a wrench; using a wrench can crack or break the boss on underside of cover.

8. Check condition of throttling orifice and, if necessary, install a new one. Reconnect agitation supply line to header.

9. Observe airlift pump for proper flow.

223−6.8.3.6 Airlift Pump Barrel. If proper agitation is not attained, the black plastic airlift pump barrel (Figure 223−31 Figure 223−32) may be clogged. Clearing the airlift pump barrel will require that the air supply tube be removed (as required in paragraph 223−6.8.3.5) and that each channel of the airlift pump barrel be ramrodded with a Teflon rod [five mm diameter and 1500 mm length (3/16 inches by five feet)]. The maintenance procedures of paragraphs 223−5.4.3.1 through 223−5.4.3.3 should be used for ramrodding of the air supply tubes.

223−6.8.3.7 Alternative Method of Installing Air Supply Tube. The air supply tube normally comes straight up from the pump through the cover; however, a special alternative tube with a 380 mm (15 in.) section on both sides of collar can be used where crossovers are so close to the top of the cell that there is insufficient room for the agitation fittings. Another instance is where the boss is broken from the bottom of the cover after being installed. This tube will go through the agitation opening on the other side of cover from where pump is located. Refer to 223−7.2.2 for details of the installation. This alternative method cannot be used on TRIDENT cells since both cover agitation openings are used for the two installed pumps.

SECTION 7.
CELL REPAIRS

223−7.1 DAMAGED CELLS

223−7.1.1 DAMAGED JARS. If a jar is broken, damaged or cracked, remove the cell, if practical, from the ship and install a spare cell. Submarine battery shops at Naval shipyards maintain charged spare cells that can be used for this purpose. If removal of the cell is impractical, jumper it from the battery circuit (paragraph 223−6.2.6).

223−7.1.2 REPLACING BROKEN COVER. For GUPPY I Mod C and TRIDENT only: to replace a broken cover, remove sealing compound, unscrew seal nuts using wrench provided, unseal cover and remove. Ensure that terminal posts are clean and dry and that the soft rubber gaskets on the posts are in place before putting on new cover. If the old gaskets are used, they should be washed and rinsed in water from the ship's demineralized (DI) water supply and dried. To ensure a perfect seal, draw up seal nuts tight.

NOTE

> Cell repairs for GUPPY I Mod E batteries should be performed by the manufacturer only.

223−7.1.3 SEALING COVER TO JAR. For TRIDENT and GUPPY I Mod C cells lay an elongated roll of sealing compound around the cover/liner joint. Use one roll on each side of the jar−to−cover joint with the rolls overlapping at the corners in the clockwise direction in an under/over fashion. Heat the sealing compound until thin enough to pour freely. Fill the cover/liner joint channel half−full with the heated sealing compound. Allow several minutes for the sealing compound to firm. Again using the heated sealing compound, fill the channel completely. Upon cooling of the joint compound, use a knife and scrape away the excess. Collect all scrapings from the battery compartment and discard as they are cut away. Test the integrity of the jar−to−cover seal per the test air procedures of section 223−2.11.4.1.

223−7.2 OTHER BATTERY REPAIRS

223−7.2.1 REPAIRING VENTILATION SYSTEM AND CHARGE SCHEDULES. When the battery ventilation system is temporarily dismantled for repairs, the repair schedule should restore the permanent battery ventilation system in time to charge the battery as prescribed.

Except in a shipyard or on extended availability where temporary ventilation is provided, charging shall not be done until the ventilation system has been completely installed and tested for air quantity and distribution. Any deviation is to be treated as an emergency. The minimum requirements for temporary battery ventilation when charging as set forth in section 223−4.5.1, shall be met.

223−7.2.2 AGITATION AIR SUPPLY TUBES. As a general rule, the air supply tube comes straight up from the pump through the cover. There are instances where this is not possible.

223−7.2.2.1 Alternative Methods. As an alternative, a special tube is used. The bottom of the tube is the same, but the top is extra long and will go to the hole on the other side of the cover where the air will be fed to the pump (Figure 223−33). This tube is used where the crossovers are so close to the top of the cell that there is not enough room for the agitation plug. Another instance is where the boss is broken from the. bottom of the cover after the jar and cover have been installed in the ship. A dummy plug and gasket are used on the broken boss. The opening on the other side of the cover is then used for the agitation system. (This configuration does not apply to TRIDENT, since two pumps are used.)

223−7.2.3 TREATING FLASH ARRESTERS FOR WATER REPELLENCY. Flash arresters that cannot pass the wet pressure drop test (paragraph 223−5.2.2.3) probably have lost their nonwetting or water−repellent characteristic. This property can be restored if the flash arrester is cleaned (paragraph. 223−5.2.2.2) and then treated according to procedure outlined in paragraphs 223−7.2.3.1 and 223−7.2.3.2 or 223−7.2.3.3. A test to determine adequacy of the treatment is outlined in paragraph 223−7.2.3.5.

223−7.2.3.1 Materials and Equipment. The following materials and equipment are required to treat flash arresters for water repellency:

a. Dow−Corning Corporation: Syloff 23 (replaces DC−23) silicone resin

b. Oven: mechanical convection 82°C (180°F)

c. Brush or dip tank

d. Draining and baking racks

e. Toluene solvent.

223−7.2.3.2 Procedure for Application by Brushing. Prepare a solution by diluting 35 grams (g) of Syloff 23 with approximately 35 milliliters (ml) of toluene. Brush inside surface of dome with one−third of the solution. Similarly apply one−third of solution to outside and brush the inside again with the final third. Place arrester, open end down, on a horizontal drying rack and dry in a mechanical convection oven at 82°C (180°F) for at least one hour. As the dome will absorb all or most of the solution, draining before oven drying is generally not necessary. The indicated weight of silicone resin will produce a dried coating of approximately 3 g. Techniques and dilution ratios should be adjusted to obtain between 2 g and 4 g of dried coating per dome.

223−7.2.3.3 Procedure for Application by Dipping. Step−by−step dipping procedures are provided in Maintenance Requirement Card (MRC) EL−18 R5. Prepare solution in a larger quantity but in the same ratio as for brushing. Solution strength may need to be increased to obtain from 2 g to 4 g of dried coating on each arrester. Dip arrester in solution and place, open end down, on a horizontal draining rack until most of excess solution has drained away (about five minutes). Place arrester, open−end down, on a horizontal drying rack in a mechanical convection oven at 82°C (180°F) for at least one hour.

223−7.2.3.4 Pressure Drop Measurement. Subject treated arrester to a wet pressure drop test outlined in paragraph 223−5.2.2.3 (see Figure 223−34). If resultant pressure drop is greater than acceptable, repeat oven drying described in paragraph 223−7.2.3.3. If the wet pressure drop value still exceeds the allowable maximum, excessive dirt or silicone resin is indicated and the arrester should be discarded.

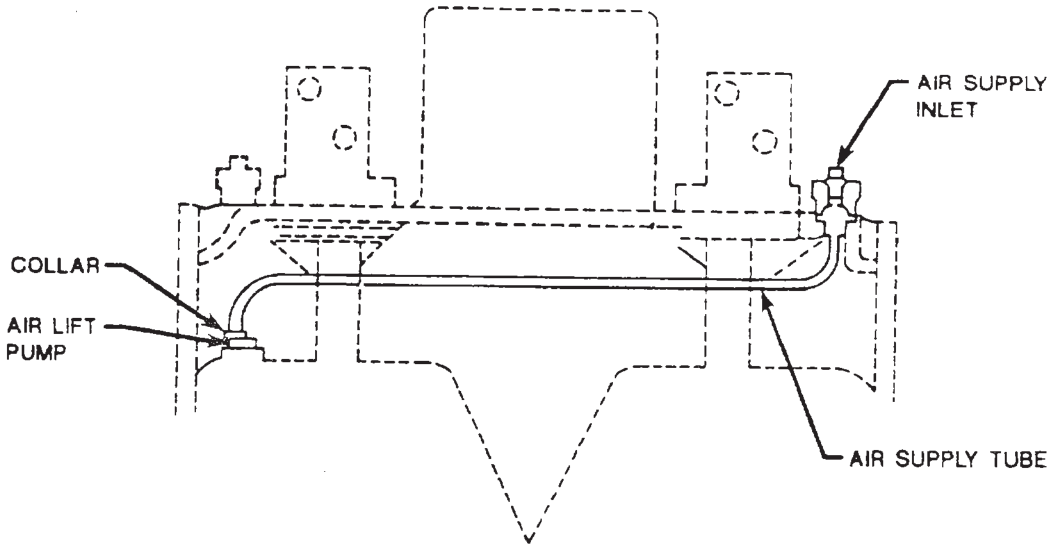


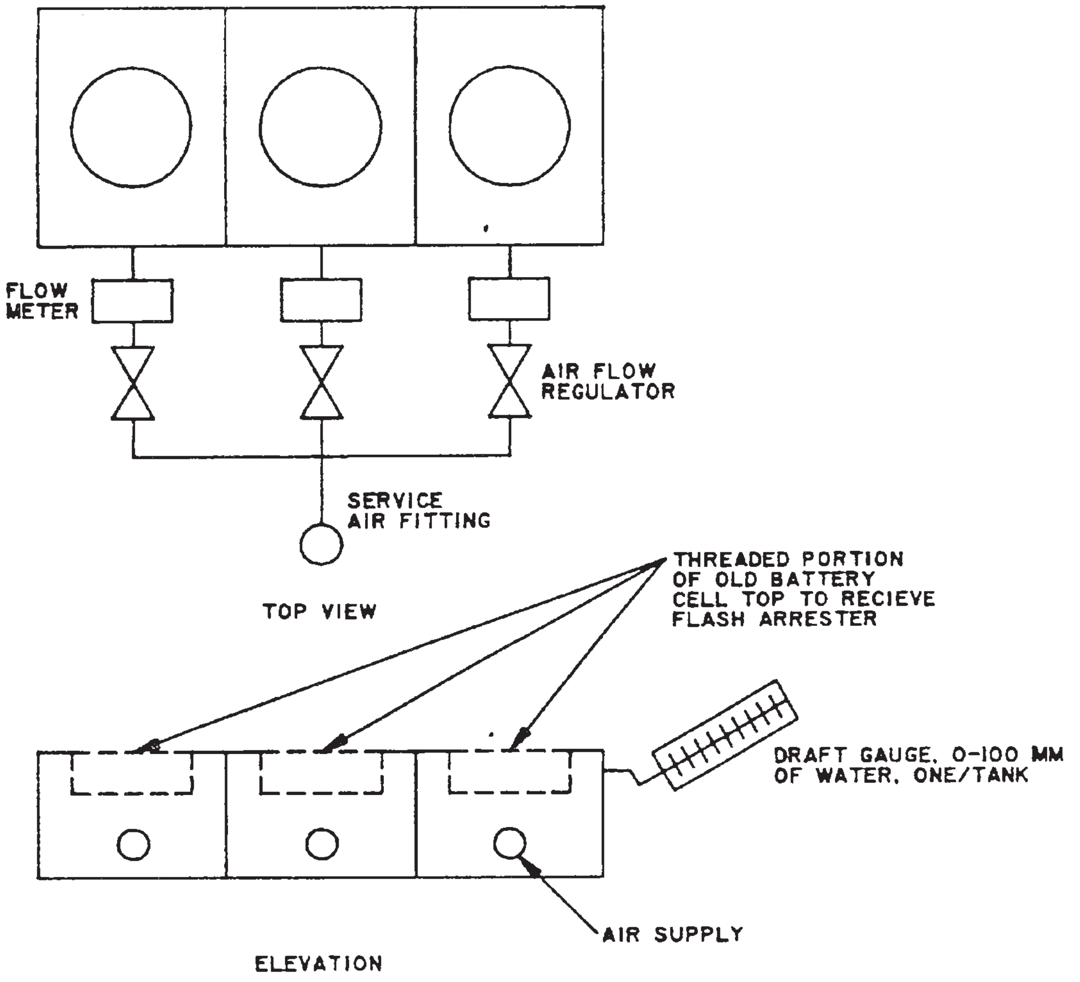
Figure 223−33. Alternative Method for Agitation Air Supply Tube

223−7.2.3.5 Silicone Resin Cure Test. Select a sample of one from each lot of 126 treated flash arresters that have successfully passed the pressure drop test. Break the dome of the selected sample into small pieces and place a 50 to 60 g sample of the pieces in a 250 ml beaker filled with 150 ml of 1.265 specific gravity sulfuric acid. Cover beaker and heat at 104°C (220°F) for two hours. Mark acid level at beginning of test and maintain this level throughout test by adding DI water. Cool and examine solution for presence of silica (waxy, gelatinous, white material), which floats. The presence of silica indicates that the silicone resin has not been properly cured and the curing procedure should be repeated on the lot of arresters. If a second selected sample fails to pass test, the lot shall be discarded.

223−7.2.4 BATTERY REPLACEMENT RESPONSIBILITY. The Force Commander is responsible for notifying the Naval Sea Systems Command (NAVSEA), via the chain of command, when the battery requires replacement.

223−7.2.4.1 Battery Replacement Scheduling. NAVSEA should be notified well in advance (not less than six months) of the predicted battery replacement date so that time will be made available for replacement, taking into account the future operations and overhaul schedule of the submarine. This is particularly important when the installed battery is considered incapable of lasting until the next scheduled replacement.

223−7.2.4.2 Replacement Battery. When battery replacement is approved by the type commander and NAVSEA, the replacement battery (including spare cells)



NOTES:
1. EACH TANK TO BE TIGHT AGAINST ADJACENT ONE.
2. NUMBER OF TANKS IS OPTIONAL.
3. EACH TANK FITTED WITH WATER DRAFT GAUGE, READING 0 TO 100 MM WATER PRESSURE.

Figure 223−34. Sketch of Test Apparatus for Wet Pressure Drop Test will be provided. The installing activity should requisition needed miscellaneous material (see paragraphs 223−2.8.1 through 223−2.10.7 and 223−7.2.4.4). If the battery is to be replaced while the ship is in dry dock, wedging should be rechecked after refloating.

223−7.2.4.3 Replacement Cells. NAVSEA has procured and stocked replacement batteries based on an estimated expiration of useful battery life. The program is subject to modification from time to time as indicated by battery reports received from the submarines. These replacement batteries are stored at supply centers and Naval shipyards. These batteries will be issued only at the direction of NAVSEA. In addition to the sets of cells sufficient for complete batteries stored at supply centers, a small number of such cells are also stored at other Naval submarine activities. These sets are generally specific battery types for ships operating in the immediate areas. These cells will likewise be issued only at the direction of NAVSEA. Jars, covers and ventilation parts are stored the same way. These items are under the cognizance of the Ships Parts Control Center (SPCC) and the Defense General Supply Center. The replacement activity should requisition sufficient parts to cover projected breakage during replacement.

223−7.2.4.4 Materials Required. The required materials, other than those noted in paragraph 223−7.2.4.2, which are generally used in connection with battery replacements and the specifications for them, are as follows:

a. Acid, sulfuric, for storage batteries, Fed Spec O−S−801

b. Adhesives FED SPEC MMM−A−121, Adhesive, Bonding Vulcanized. Synthetic Rubber to Steel

c. Paint, acid−resisting, TT−V−51, Varnish: Asphalt

d. Paraffin, VV−W−95, Wax, Paraffin, Technical

e. Battery sealing compound, DOD−C−2687, Compound, Battery−Sealing. (Metric)

f. Tape, insulating rubber

g. Other materials, including: kerosene, sodium bicarbonate and protective and first−aid supplies

h. For renewal of individual cell voltmeter leads, use white wire in accordance with MIL−W−16878, **Wire, Electrical, Silicone Rubber**. Insulated, 200°C, 600 Volts types B−16, D−16, E−16, or EE−16

i. Rubber lining for battery tank in accordance with MIL−S−2912.

223−7.2.5 REPORTING. The submarine battery record book, NAVSEA 9320/1 (6−75), NSN 0116−LF−093−2005, is normally provided with each new set of cells for a new battery and is shipped in the same crate as the battery service manual. The new record book should include the filling and initial charging data. To obtain a battery record book, NAVSEA 9320/1 (6−75), a submarine should submit a stock form and publications requisition on Form DD 1149 to the Naval Publications and Forms Center, Philadelphia, Pennsylvania. The installing activity, when replacing the battery, shall notify NAVSEA that the old record book is available. The book shall be retained for one year thereafter for forwarding to NAVSEA if requested. If not requested within this time, the book shall be destroyed.

SECTION 8.
OVERHAUL

223−8.1 BATTERY OVERHAUL

223−8.1.1 BATTERY REPLACEMENT. The replacement of submarine main storage batteries is not usually scheduled to coincide with ship overhaul. Battery replacement instructions concerning assembly, accessory equipment, preparation, operation, ventilation and installation are covered in the first four sections of this volume. When the battery is not being replaced during a regularly scheduled overhaul, the battery and all auxiliary equipment and accessories should be thoroughly checked by ship's force instead, to ensure that they are capable of safe and efficient operation. The material condition of a retained battery is to be maintained at the normal ship operations level, not as if it were new.

223−8.1.2 WHEN REPLACING BATTERIES DURING OVERHAUL. Since prolonged inactivity reduces battery life, inactive periods should be kept to a minimum, as follows:

a. Plan, especially for extended overhauls, to maintain the existing battery in place as long as possible, installing the new replacement battery within six months or less of the end of overhaul.

b. Do not wet down a new battery to be used as a replacement until just prior to installation.

223−8.1.3 CARE BEFORE AND DURING OVERHAUL. Wet batteries that have been in active service and are not to be used for a significant period should be given an equalizing charge immediately prior to the start of the idle period. Following that equalizing charge, the battery may be maintained either on open circuit or on auxiliary load. Open circuit is preferable, and is required if the idle period is to be longer than six weeks. Consult Section 3 for routine to be followed during overhaul.

223−8.1.3.1 Capacity Test Discharge Prior to Overhaul. Within the two month period of operation preceding a major overhaul, conduct a capacity test discharge (paragraph 223−5.5.4). Report the capacity obtained to the Naval Sea Systems Command (NAVSEA) via an addendum to the Quarterly Battery Report and forward all pertinent discharge data to the manufacturer. Include copies of the recorded individual cell readings on the equalizing charges conducted during the two months before the test and the equalizing charge immediately following it.

223−8.1.3.2 Required Charging During Overhaul. Give the battery an equalizing charge (paragraphs 223−3.2.4 and 223−3.2.8) at the start of the overhaul period and place the battery on open circuit.

223−8.1.3.3 Scheduling Charges During Overhaul. Prepare a schedule of dates for conducting equalizing charges (paragraph 223−3.6.4) at six−month intervals for lead−calcium batteries. If shipyard work will prevent the conducting of the charge on schedule, conduct the charge before this work starts, reducing the minimum ampere−hour (Ah) of charge as required by Section 3. Except in an emergency, the period between charges shall never exceed seven months. If shipyard work takes longer, temporary ventilation, agitation and charging systems must be provided as necessary to support the charge. If at any time during the inactive period, miscellaneous discharges cause the specific gravity to fall below the value specified in the battery service manual, the specified charge should be given and a new schedule established.

223−8.1.3.4 Trickle−Discharge Current Regulation. Make certain that the motor generator speed and voltage regulators are operating correctly to ensure that the trickle−discharge (paragraph 223−3.5.14) is maintained during high transit of loads on the main ship's service electrical power system.

223−8.2 BATTERY ELECTRICAL SYSTEM

223−8.2.1 METERS. All electrical meters shall be checked and recalibrated by the overhaul or installing facility meter shop personnel. These include:

a. Total battery and individual cell voltmeters

b. Ammeters

c. Ampere−hour meters

d. Ground detector ohmmeter.

If ammeter recalibration cannot provide accuracy over the entire scale, and replacement ammeters are not available, recalibrate accurately for prescribed finishing rate of charge for the battery. Upon reinstallation and prior to completion of overhaul, all meters should be checked for calibration, in place.

223−8.2.2 LEADS AND FUSES. All electrical meter leads should be checked for continuity and connections. They should be cleaned and tightened. Any frayed, broken or badly worn leads should be repaired or replaced. All fuses should be checked and defective ones replaced. Fuse boxes, in−line fuse holders and plug−in panel contacts should be cleaned and tightened.

223−8.2.3 SHUNTS. All shunts should be removed and their resistance or millivolt drop electrically checked against their rated values in the meter shop. Defective shunts should be repaired or replaced.

223−8.2.4 ICV MONITOR (ICVM) SYSTEM PLUG−IN BOARD. Plugs, jacks and wires should be checked for excessive wear and replaced as required. The panel should be cleaned and all connections tightened. Board connectors should be cleaned and tightened. Panel board should be checked for proper operation and accuracy prior to the first charge after completion of work.

223−8.2.5 INTERCELL CONNECTORS, QUICK DISCONNECTS AND END−OF−ROW CROSSOVERS. Check, inspect and clean intercell connectors, battery quick disconnects and crossovers as follows:

a. Intercell Connectors. Inspect and clean contact area of bus work. If copper shows through, replate with lead or silver (paragraph 223−6.2.6.4) where necessary. Tighten all intercell connector nuts and bolts to a torque of 57 to 62 newton−meters (500 to 550 inch−pounds) (paragraph 223−2.11.8).

b. Quick disconnects. Inspect and clean the operating mechanism. Lubricate as necessary. Inspect disconnect for proper bus bar alignment and line contact.

c. End−of−Row Crossover. Inspect and clean contact area of bus work. If copper shows through, replate where necessary, similar to a. above. This bussing is insulated using plastisol or by wrapping with mica or glass tape (or both) coated with an insulated varnish. Check and reinsulate as outlined in paragraph 223−2.11.10.

223−8.2.6 HIGH RESISTANCE TERMINAL CHECK. On all installations of batteries to be retained, visually check terminals for evidence of high temperature or arcing, such as melted insulation and plastic seal nuts. Report deficiencies to NAVSEA.

223−8.2.7 BATTERY CABLE CHECKS. Battery cables should be given a close visual inspection for satisfactory conditions as follows:

WARNING

Component shall be deenergized and properly tagged out prior to inspection.

a. Cables shall be tested and inspected using the guidelines and procedures outlined in **NSTM Chapter 300, Electric Plant General,** Section 3.

b. Cables shall meet the acceptance requirements of **NSTM Chapter 300, Electric Plant General,** Section 1.

c. Evidence of overheating, chafing, and frayed or chipped insulation is not acceptable.

d. Loose electrical or mechanical connections are not acceptable.

e. Damaged sheaths are not acceptable.

223−8.3 BATTERY WATER, ELECTROLYTE AND RELATED SYSTEMS

223−8.3.1 ANALYSIS − ELECTROLYTE AND WATER. Submit electrolyte samples (paragraph 223−5.5.5) from at least 10 cells in the battery well to a Government laboratory for complete spectro−analysis. A 150 ml (five ounce) sample of water from each redistilling plant, in addition to a 150 ml (five ounce) sample of water that has passed through the ion exchangers, shall be submitted for analysis. The analysis shall show the percentage of each of the impurities listed in Table 223−7 and Table 223−8.

223−8.3.2 ION EXCHANGERS. Renew exchange resin to restore its purifying ability (paragraph 223−5.2.1).

223−8.3.3 BATTERY WATER. Ship's demineralized (DI) water supply shall be checked by means of the silver−nitrate test (paragraph 223−5.3.2).

223−8.3.4 ELECTROLYTE LEVEL GAUGE. Check electrolyte level gauge for proper normal or zero setting as shown in the battery service manual.

223−8.3.5 WATERING GUNS. To prevent overwatering (paragraph 223−1.9.11), check watering guns for proper operation.

223−8.3.6 THERMOMETERS. All thermometers should be checked for accuracy against a known standard. Use of mercury−in−glass thermometers is prohibited in submarines.

223−8.3.7 HYDROMETERS. Check all hydrometers in accordance with section 223−5.5.3. Check floats for cracks or broken nibs. Check that the paper scale inside the float stem has not been jarred out of position. All electrolyte drawn up in the hydrometer barrel should be replaced in the cell from which it was taken (section 223−6.4.4.1, paragraph b). Any spilled acid should be immediately cleaned from the top cover of the cell, the compound seal and the perimeter of the jar.

223−8.3.8 ELECTROLYTE AGITATION SYSTEM. The electrolyte agitation system is a primary system for all battery types and must be operational at all times regardless of the battery routine. See paragraph 223−5.4 for system functional check, routine maintenance and operational requirements during maintenance.

223−8.4 BATTERY INSTALLATION

223−8.4.1 REPLACEMENT BATTERY. If the battery is to be replaced, follow installation procedures as outlined in Section 2, the applicable manufacturer's service manual and shipyard procedures. If the battery is to be replaced while the ship is in dry dock, wedging should be rechecked after refloating.

223−8.4.2 INSTALLED BATTERY RETAINED. In instances where the installed battery is being retained, sections 223−8.2.6 and 223−8.4.2.1 through 223−8.4.3 are pertinent. The material condition of a retained battery is to be maintained at the normal ship operations level, not as if it were new.

223−8.4.2.1 Battery Tank. Check the battery tank for condition of exposed lining, paint, insulation and similar items, and repair and refurbish where possible (paragraph 223−2.11.10).

223−8.4.2.2 Wedges. Check battery well wedges for any loosening. Wedges should not be able to be lifted and dropped back in place (paragraph 223−2.11.6). Loose wedges shall be replaced or tightened with filler wedges.

223−8.4.2.3 Cell Jars and Covers. Visually examine cell jars, covers and sealing compound for cracks. Replace as necessary per Section 7.

223−8.4.2.4 Air Pressure Test. Any new cell to be installed must pass the air−test at seven kilo−Pascals (kPa) (1 lb/in^2) for one minute (paragraph 223−2.11.4.1).

223−8.4.2.5 Dielectric Test. Any new cell to be installed must pass the dielectric test (paragraph 223−2.11.4.3).

223−8.4.3 GROUND RESISTANCE CHECK. Prior to completion of overhaul and subsequent to completed battery installation, check the battery for grounds (paragraphs 223−6.6.1 through 223−6.7.9).

223−8.5 VENTILATION

223−8.5.1 VENTILATION SYSTEM. Ensure that ventilation system meets requirements of Section 4. See that all ducts are clean and free from corrosion and that all valves, dampers and blower impellers are in proper operating condition and mounted in the proper direction. Ascertain that impellers are installed correctly and that valves and dampers do not leak.

223−8.5.2 HYDROGEN SURVEY. Conduct a complete set of battery compartment ventilation system tests per paragraph 223−4.6.

223−8.5.3 HYDROGEN DETECTORS. To ensure that hydrogen detectors provide accurate read−

ings, arrange for a check by shipyard personnel. This check will reduce reading errors caused by problems such as incorrect bulkhead valve settings (paragraph 223−4.2.4).

223−8.5.4 BATTERY AIRFLOW METERS. Airflow meters indicate directly whether ventilation is safe. Take care to ensure that meters are installed properly and are checked by qualified personnel. Be certain that venturi meters are calibrated (paragraph 223−4.2.2 or 223−4.2.3).

223−8.5.5 HYDROGEN−CARBON MONOXIDE BURNERS. Hydrogen−carbon monoxide burners should be renewed during overhaul. Check for proper service and operation.

223−8.5.6 FLASH ARRESTERS. Inspect, test and clean flash arresters in accordance with paragraphs 223−5.5.10.

223−8.6 TESTING AND REPORTING AFTER OVERHAUL

223−8.6.1 REPORT ON VENTILATION SYSTEM. The ventilation system report shall contain results of the ventilation survey (paragraph 223−4.6.9) for all submarines.

223−8.6.2 OVERHAUL REPORT ON BATTERY AND RELATED SYSTEMS. The report on the overhaul of battery and related systems shall certify that the battery accessories and auxiliary equipment have been thoroughly checked for proper operation and that necessary repairs and required tests have been made. The report shall summarize equipment condition at the beginning of overhaul, tell what equipment was repaired or replaced and state that the complete battery and associated auxiliary equipment and systems are in good condition, completely assembled, properly installed and ready for use.

223−8.6.3 REPORT ON CAPACITY TEST DISCHARGE SUBSEQUENT TO OVERHAUL. Between the sixth and tenth week of operation following a major overhaul, a capacity test discharge is to be conducted. If a submarine has received a new battery in the yard, the test discharge should be made within six months following the yard period. If less than eight cycles have been accumulated after the yard period and prior to the test discharge, capacity may be less than 90 percent. Cycling in the battery shop should not be included in the eight cycle figure. Report the capacity obtained to NAVSEA via the Quarterly Battery Report and forward all pertinent discharge data to the manufacturer. Include copies of the individual cell readings recorded on the equalizing charges prior to and following this test. This report also should include any discrepancies not corrected during overhaul.

SECTION 9.
SAFETY PRECAUTIONS

223−9.1 NEED FOR PRECAUTIONS

223−9.1.1 BACKGROUND. Numerous precautions must be observed in the operation and handling of lead acid storage batteries to ensure the safety of personnel and prevent damage to the batteries. Practices that result in rapid battery deterioration increase the probability of accidents and injury to or loss of personnel. Consequently, all precautions ultimately contribute to personnel safety even when their immediate purpose is to prevent battery damage.

223−9.1.2 HAZARDS. The hazards associated with lead acid storage batteries are due primarily to the energy stored in the battery, the hydrogen evolved from the cells, the concentrated acid used in preparing electrolyte, electrical shocks from grounds and battery salting.

223−9.2 PRECAUTIONS AND PREVENTIVE PROCEDURES

223−9.2.1 MAXIMUM SAFE HYDROGEN CONCENTRATION. The hydrogen concentration in all parts of the ventilating system must be kept below three percent at all times to prevent an explosion. A mixture of air and hydrogen with four to eight percent hydrogen will burn if ignited by a spark or flame. Concentrations above eight percent will explode with a force that increases with the increasing hydrogen concentration. In as much as a spark to ignite the mixture is nearly always present in a submarine, the only precaution is to prevent the hydrogen concentration from too closely approaching the flammable limit. A three percent concentration is considered to be the safe maximum. Detailed instructions for keeping hydrogen concentration at a safe level are given in Section 4.

223−9.2.2 PREVENTION OF HYDROGEN FIRES AND EXPLOSIONS. Hydrogen gas may be evolved from a cell on stand, discharge or charge. If allowed to accumulate in sufficient concentration, it forms a flammable and explosive mixture that may be ignited by a flame or spark.

a. To prevent hydrogen fires and explosions, ventilate on stand and discharge in accordance with paragraph 223−4.3.2.9. Ventilate on charge in accordance with paragraphs 223−4.3.2.1 through 223−4.3.2.8. Referenced paragraphs also include discharge. When reestablishing battery ventilation after it has been completely stopped, or after a battery compartment has been sealed, proceed in accordance with paragraph 223−4.4.3. Check the ventilation system when installed (paragraph 223−2.12.1) and at each overhaul (paragraph 223−5.5.6) to ensure the ventilating requirements are met.

b. Lighted matches, pipes or cigarettes, or cigarette or pipe lighters are not allowed within a battery tank at any time.

c. Have airflow meters and hydrogen detectors checked in accordance with planned maintenance system (PMS) instructions. Read the hydrogen detector hourly during submerged operation. Energize hydrogen burners when necessary (paragraph 223−1.9.7).

d. Keep the cell service openings closed except when they must be opened to take readings or add water.

e. Station a fire watch in the well at all times when hot work is being performed at the well boundary. Have insulated carbon dioxide (CO_2) extinguishers at hand for minor fires.

223−9.2.3 PROCEDURE IN CASE OF BATTERY FIRE. A battery fire is nearly always preceded by a hydrogen explosion. Great care is required in fighting such a fire to avoid creating another explosion.

a. For some submarine classes, a battery well fire could cause excessive heating of the well overhead, which forms the weapons space deck. Temperatures must be closely watched and the weapons cooled by water or jettisoned, if necessary. Further guidance is contained in Section 6 of the Damage Control Books, in the subsection entitled Torpedo or Mine System Fire.

WARNING

NEVER attempt to extinguish a battery fire by pouring water on the battery; the hydrogen and oxygen generated by electrolytic currents could produce a violent explosion.

b. Firefighting shall be in accordance with **NSTM Chapter 9930, Firefighting−Ships**. For all submarines operating at sea, the safest and most effective method available for fighting a battery well fire is through oxygen starvation. Securing the well and stopping all ventilation within (including the battery air agitation system) can deprive the flames of oxygen. During routine maintenance operations (at sea or in port) when hot work is performed on the boundary of the well, a fire watch must be stationed in the well.

WARNING

To avoid short circuiting the battery, never use an uninsulated fire extinguisher in the battery well Insulated extinguishers are required for use by fire watch personnel when hot work is performed on the boundary of the well or to protect against a minor fire when conditions prohibit isolation of the well, that is, during various stages of overhaul.

c. It is not always possible to isolate the battery well during various stages of overhaul. Fire protection for a minor fire under those conditions must be provided by insulated CO_2 fire extinguishers in order to avoid battery short circuiting and electrical shock to personnel. Two insulated CO_2 fire extinguishers are to be maintained near the battery well for this purpose. For procedure used to insulate fire extinguishers, see paragraph 223−9.3.3.

WARNING

Do not pour water into concentrated sulfuric acid. The heat generated will cause a violent reaction. Sulfuric acid is highly corrosive. Neutralize with sodium bicarbonate and wash up spillage immediately with water from the ship’s demineralized (DI) water header. Wear suitable protection when handling acid.

223−9.2.4 PRECAUTIONS IN HANDLING ACID AND ELECTROLYTE. The concentrated sulfuric acid used for making electrolyte can cause painful and serious burns and extensive equipment damage. Store sulfuric acid only where it will not be exposed to freezing temperature (paragraph 223−9.1.2). Keep plastic and metal acid carboys securely stoppered (223−9.1.2).

Always pour acid slowly into water and never water into acid (paragraph 223−2.9.2.7). When handling either acid or electrolyte, personnel shall always wear rubber aprons, rubber boots, rubber gloves and face shields to protect skin and eyes from contact with acid (paragraph 223−9.2.1). Treat acid burns promptly in accordance with paragraph 223−9.2.4.1.

223−9.2.4.1 Treatment of Acid Burns Aboard Ship and at Shore Facilities.

a. Aboard ship, if concentrated acid or electrolyte comes in contact with the skin, immediately wash the affected area freely with a large quantity of freshwater for approximately 15 minutes. If concentrated acid or electrolyte comes in contact with the eyes, flush with freshwater for a minimum of 15 minutes, ensuring that both upper and lower lids are pulled out sufficiently to allow water to flush under them. In either case, the Medical Department must be notified of the accident as soon as possible and requested to come to the site. If the Medical Department cannot be notified, do not attempt to transport the victim to sick bay prior to washing or flushing with water for 15 minutes. In an extreme emergency where freshwater is not available, seawater may be used, but only as a last resort. Clothing that may have been splattered with acid should be removed promptly. Contaminated skin areas should be treated promptly as well.

b. At shore facilities, all battery maintenance, storage and charging facilities must have an eyewash and deluge shower within easy reach of a person who has been burned or temporarily blinded by concentrated acid or electrolyte. If an accident occurs in a remote or primitive area, pour freshwater from buckets or other suitable containers on the affected areas or into the eyes; however, a steady stream of freshwater from a garden hose would, if available, be preferable. Proper medical attention should be given without delay.

223−9.2.5 ELECTRICAL PRECAUTIONS. The batteries in a modern submarine can release up to several thousand kilowatts of electrical energy. They store sufficient energy to lift the entire ship vertically for a distance of nearly 1.6 kilometers (one mile). Any failure in the electrical equipment or circuits that releases this energy without direction, may cause extremely rapid heating, melting of conductors and fires. Keep all connections tight to prevent excessive heating due to contact resistance, to avoid accidental short circuits and to keep the batteries clean and free from grounds and other leakage paths that may conduct a destructive current. Observe the following precautions at all times to maintain control of the electrical energy of the battery:

a. In the battery installation, provide ample airspace between conductors of opposite polarity and between conductors and ground; use plastisol insulating boots, glass melamine or glass silicone for insulation; do not use phenolic material; provide ample creepage distance, and tape bus bars (paragraph 223−2.11.10).

b. Use only insulated tools and nonmetallic flashlights around a battery. Be extremely careful never to short−circuit any part of the battery. There are no circuit breakers in the cells to open up a short, and no switches that can be thrown to deenergize the battery terminals.

c. Make no repairs to the connections when current is flowing. An accidental opening of the circuit when current is flowing may start an extremely destructive arc.

d. Keep cell tops clean (paragraph 223−5.5.1).

e. Keep the battery clear of grounds and leakage paths (paragraphs 223−6.6.1 through 223−6.7.9, inclusive).

f. Use the ground detector to test for grounds before and during a charge and, except in an emergency, do not charge a battery for which the resistance to ground from battery alone is less than 100,000 ohms (paragraph 223−6.7). Never operate the ground detector when personnel are in the battery tank.

g. Measure the ground resistance before doing any work that involves touching a battery cell terminal. Insulate the body from ground by using a rubber sheet over parts of the ship structure with which contact might be made (paragraph 223−6.7.9).

h. In case of a short circuit in the cables between the battery and the Emergency Power Control Panel (EPCP), disconnect the battery from the cables. Circuit breakers are provided in all submarines for this purpose.

i. Never store loose gear in the battery tank. Gear such as cleaning rags, hydrometer boxes, pieces of wire and tools must be removed immediately after use.

j. Never touch a live conductor of an electrical circuit, ungrounded or grounded.

k. High system insulation readings from a megohmmeter test do not mean that the system is safe to touch. Insulation resistance tests are made to ensure that the system will operate properly, not to indicate that the system is safe.

l. Know and follow the electrical safety instructions contained in **NSTM Chapter 300, Electric Plant General**.

WARNING

Never perform any battery well maintenance of any kind without additional personnel present.

223−9.2.6 EMERGENCY PROCEDURE WHEN BATTERY IS SALTED. If salting (entry of chlorine into a cell, usually from seawater) occurs in an emergency when battery capacity cannot be reduced, take the following steps:

1. Secure air agitation system. Ventilate ship to outside atmosphere.

2. If the flooded cells have an electrolyte level above normal, draw electrolyte level down to normal. Restore air agitation system.

3. Put the battery on charge at a rate sufficient to cause active gassing while maintaining a hydrogen concentration below three percent in the battery exhaust. Take precautions to prevent battery gases from entering other compartments (Section 4). Ventilate at maximum rate.

4. Continue the charge until the specific gravity is constant and chlorine is no longer being evolved from the cells.

5. At the first opportunity, have the electrolyte analyzed by a qualified chemist and replace it if necessary.

223−9.2.7 PROCEDURE IF SALTING OCCURS WHILE SUBMERGED. If the salting occurs while submerged, secure agitation system and surface immediately if possible. If this is not possible, draw electrolyte from the salted cells to the top of the plates and clear the ship of chlorine by the use of the

CO_2 absorbent in the manner prescribed by **NSTM Chapter 510, Ventilating, Heating, and Air−Conditioning Systems for Surface Ships**.

223−9.2.8 PROCEDURE AND PRECAUTIONS IN REDUCING SUBMARINE BATTERY COMPARTMENT AMBIENT PRESSURE. The gas contained in a submarine battery cell is mostly hydrogen. If a battery compartment is pressurized (for example, by an air pressure compartment test or by leakage of high−pressure air), the hydrogen in the battery cells is compressed and diluted with air to a concentration depending on the absolute values of the initial and final pressures. In any practical case, the air dilution is not sufficient to reduce the hydrogen concentration to the prescribed maximum concentration of three percent. On the subsequent depressurization of the compartment, the air−hydrogen mixture will be released from the battery at a rate proportionate to the rate of pressure reduction. The rate of hydrogen evolution must therefore, be controlled so that hydrogen concentration never exceeds three percent at any point in the system.

a. The precautions and procedures in this section compensate for the known factors that could contribute to the hydrogen hazard in the course of reducing pressure in submarine battery compartments. They also provide for the welfare of personnel who may be within the area under pressure. They are not intended to conflict with existing instructions dealing with negative pressure during snorkel operation, but are restricted to pressures more than 3.5 kilo−Pascals (kPa)(0.5 lb/in^2) above atmospheric pressure. The principle objective is to ensure a safe reduction in pressure in the course of air tests or whenever a battery compartment has become pressurized for any reason.

b. As a general rule, avoid reducing pressure at a rate greater than 3.5 kPa (0.5 lb/in^2) per minute. Do not attempt to reduce hull pressure while a battery is on charge. The battery must first be placed on zero float or on a low rate of discharge.

223−9.2.9 PROCEDURE AND PRECAUTIONS FOR TESTING BATTERY COMPARTMENT. Prepare and test battery compartments as follows:

1. Begin hydrogen detector operation 20 minutes in advance of the test. On ships where the sensing element of the hydrogen detector is located outside the compartment to be tested, special arrangements shall be made to monitor hydrogen in the battery compartment.

2. Operate the battery ventilation system on high speed for at least 20 minutes in advance of the test.

3. Just prior to starting a test, line up the battery ventilation for emergency recirculation. Maintain ventilation in this manner until normal ventilation can be restored after the test.

4. Operate the battery tank recircuiting fans on all ships where such fans are required by plan.

5. During the pressure reduction, do not allow the hydrogen concentration in the exhaust duct to exceed 1.5 percent at any time. If this limit is reached, maintain the existing pressure level by applying compressed air and simultaneously bleeding it off at the same rate. Continue ventilating in this manner until the hydrogen detector reading is below 1.0 percent before proceeding with a gradual reduction in pressure or any other stage of the test.

6. To prevent electrolyte carryover into the air supply piping, ships using the ship's compressed air supply for agitation are to close the shutoff valve and isolate the sys−

tem. On other ships, the air agitation system air supply is from the battery compartment.

223−9.2.10 HOT WORK DURING DOCKSIDE CHARGING. The following procedures and restrictions apply when hot work or other flame or spark−producing work is done during battery charges with submarines at dockside:

a. Blow torches, welding equipment, and the like shall not be used in a submarine during a battery charge or for 20 minutes after completion of the charge (paragraph 223−3.2.4). This restriction is intended to eliminate all sources of ignition of the explosive hydrogen gas evolved by the battery during charge.

b. The battery and its associated ventilation system are completely contained in one major watertight compartment, forward in the ship. The three principal main propulsion and machinery compartments can be isolated from the battery exhaust ventilation path. Thus, these two areas of the ship can be treated as two separate hulls for the purpose of complying with procedures a, d and e.

c. While conducting battery charges at dockside, restrictions in procedures a, d and e need not apply inside the ship in those spaces separated from the compartment containing the battery by a completely sealed watertight bulkhead, such as the forward missile compartment bulkhead. (The bulkhead shall be inspected immediately before the hot work is undertaken to ensure that watertight integrity has been retained.) The battery exhaust shall be discharged overboard via ductwork located within the compartment containing the battery. For this purpose, either temporary ventilation ductwork or the low−pressure (LP) blower overboard exhaust system may be used if the LP blower is located within the compartment containing the battery. In addition, all access hatches within 15 meters (50 feet) of the battery ventilation exhaust to the atmosphere are to be sealed. Any bulkhead or hatch sealed for this purpose shall remain sealed for 20 minutes after the battery charge is completed.

d. Sparking of electrical apparatus shall not be allowed within the battery tank.

e. Lighted matches, cigarettes or pipes shall not be allowed within a battery tank or in the areas adjacent to the battery tank at any time during charge.

f. It should be understood that the practices outlined in this paragraph, although considered safe, are not intended to relieve anyone involved of the responsibility for maintaining absolutely safe conditions throughout a charge.

223−9.3 MISCELLANEOUS PRECAUTIONS

Additional precautions that must be observed in the operation and handling of storage batteries are summarized as follows:

a. Brush off all packing material before opening the inner packing case if cells are shipped in double boxes (paragraph 223−2.3.2).

b. Keep cells in their packing cases until they are to be installed (paragraph 223−2.3.2).

c. Never drag jars on the bottom edges or place them so that the entire weight of the cell rests on the edges (paragraph 223−2.3.2.1).

d. Make a dielectric and air test on each jar before the cell is lowered into the ship (paragraph 223−2.3.2.1).

e. See that the service cap is in place before lowering a cell into the ship (paragraph 223−2.11.4.4).

f. Never use soft wood for the battery wedges (paragraph 223−2.11.6).

g. Operate the air agitation system at all times (paragraph 223−3.5.16).

h. When working around open cells, always exercise care to keep foreign material of any nature from falling into the cells.

i. Always have new electrolyte analyzed prior to use (paragraph 223−2.9.2.6).

j. Do not add acid of greater specific gravity than 1.350 to a battery (paragraph 223−2.10.3.2).

k. Only add only DI water or water that analysis has found to be pure enough for battery use (paragraphs 223−2.9.2.3 and 223−5.3.1).

l. Test water from the ship's demineralized water header for chloride before it is used in battery maintenance (paragraph 223−5.3.2).

m. Always test DI water for chloride before putting it in a battery (paragraph 223−5.3.2).

n. Do not use the battery watering hose for any other purpose.

o. Never allow the electrolyte to fall below the minimum level specified on the curves and data plan (paragraph 223−5.3.3), and exercise great care not to fill any cell above the normal level (paragraph 223−5.3.3.1).

p. Never allow a battery to stand in a discharged condition for more than 24 hours.

q. Do not operate a battery above 54°C (130°F) except in an emergency. Refer to paragraphs 223−3.2.12 and 223−3.5.10.

r. Do not, except in an emergency, discharge a battery below the given low−voltage limit (paragraph 223−3.5.4).

s. Note: For USS DOLPHIN, if it is necessary to jumper out one or more cells from one battery, compensating cells should be jumpered from the other batteries.

t. When chlorine gas is detected, put on emergency air−breathing apparatus (EAB).

u. Study battery installation and ventilating system, and plan in advance what to do in an emergency (paragraphs 223−4.4 and 223−9.2.2).

WARNING

Never perform any battery well maintenance alone.

223−9.3.1 PRECAUTIONS FOR JUMPERING CELL OUT OF BATTERY. Observe the following precautionary procedures when jumpering a cell out of the battery:

a. Place battery on open circuit; open battery breakers

b. Observe procedure for entering battery well (paragraph 223−3.4.4)

c. Ensure that all precautions and conditions are met for opening of electrical disconnects. Open battery quick−opening disconnect switches

d. Use insulated tools

e. Ventilate battery tank

f. Never work alone when jumpering out a cell

g. Torque connections (paragraph 223−2.11.8)

h. Maintain air agitation on jumpered cells to provide uniform air pressure for the rest of the battery cells.

223−9.3.2 SAFETY IN VENTILATION. Detailed instructions about safety aspects of battery ventilation are given in paragraphs 223−3.4.2 and 223−4.3.

223−9.3.3 INSULATION OF CO_2 FIRE EXTINGUISHERS. Carbon dioxide (CO_2) extinguishers should be insulated as follows:

1. Completely empty the contents of the extinguishers. Ascertain that the hydrostatic test date stamped on the cylinder neck is recent.

2. Remove cylinder valve and replace with properly threaded eye bolt plug (locally fabricated).

3. Apply a uniform plastisol coating (conforming to MIL−P−20689, Type II, Class 1) to a dry film thickness of 35 ± 5 mils to provide the required dielectric strength. Application instructions and information are contained in **NSTM Chapter 631, Preservation of Ships in Service (Surface Preparation and Painting)**, and in MIL−P−20689. Do not coat over the cylinder test date on the neck; leave no more than 18 centimeters (cm) (seven inches) of the neck uncovered. Quinquennial (every fifth year) test requirements and other compressed gas cylinder data are listed in **NSTM Chapter 550, Industrial Gases; Generating, Handling, and Storage.**

4. To ensure uniformity of plastisol coating for dielectric strength, thickness readings should be taken every 10 cm (four inches) along the length of the cylinder and every 10 cm (four inches) around the circumference. Thickness measurements should be made with a magnetic−type gauge specified in NSTM Chapter 631.

5. If properly applied, plastisol is not porous. Porosity can be checked using the electrical conductivity test described in MIL−R−15058G. The K−D Bird Dog Instrument referred to in that specification can also be used for conductivity measurements for determining porosity.

6. Reinstall cylinder valve. Recharge cylinder with CO_2 and check for leaks in accordance with **NSTM Chapter 9930, Firefighting−Ships**.

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