Metro

P3010
Los Angeles LRV

BATTERY

Section 1100
RUNNING MAINTENANCE & SERVICING MANUAL

LIST OF EFFECTIVE PAGES

Insert latest changed pages; dispose of superseded pages in accordance with applicable regulations.

NOTE: On a changed page, the portion of the text affected by the latest change is indicated by a vertical line.

Total number of pages in this section (1100) is **44** consisting of the following:

Draft	Draft	December 2014
Draft	Final Draft	October 2015
Draft	Final Draft-A	July 2016
Draft	Final Draft-B	March 2018

PAGE	CHANGE NO.	PAGE	CHANGE NO.
i through x	Final Draft-B		
1-1 through 1-4	Final Draft-B		
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SAFETY SUMMARY

Some of the procedures in this section are preceded by warnings/cautions regarding potential hazards in handling this equipment. These warnings/cautions should be carefully read and understood before proceeding. Failure to observe these precautions may result in serious injury to personnel performing the work and/or bystanders. The key warnings for this equipment are as follows:

Electrical - The electrical equipment described in this section operates at voltages and currents that are extremely dangerous to life. Personnel should closely observe all generally prescribed cautions and warnings before performing any work on the LRV.

Chemicals – Follow safety precautions for handling hazardous chemicals as provided by the manufacturer. The manufacturer's warnings should be closely heeded to avoid personal injury.

Location – Special caution should be taken when accessing or servicing equipment located on the roof and under the car.

Weight – To prevent possible personal injury when attempting to remove or install equipment on the vehicle, adequate support of a lifting device must be used to prevent the equipment from falling. Personnel's failure to heed these warnings could result in severe injury or death and or damage to the equipment.

Contact – Some components in this equipment attain temperatures that can cause severe burns. Closely follow all warnings and recommended procedures for handling these components.

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CHAPTER 1.0

GENERAL DESCRIPTION

1.1 Introduction

The information provided in this manual is intended to help operator and maintenance personnel obtain the best performance and maximum life from their Saft vented nickel-cadmium storage batteries. This manual provides instructions to users and technicians on the operation, maintenance, repair, overhaul and otherwise care for the battery.

The information applies only to vented sintered/PBE nickel-cadmium batteries made by Saft. In the rail transit industry, the nickel-cadmium battery is used to store energy for the supply of emergency power to low voltage circuits during high voltage loss or charging equipment failure.

A battery is considered as an assembly of cells in stainless steel crates installed in a battery slide-out tray within the compartment by the car builder. This includes the cells in crates (battery crate assemblies), cables, and may include lugs, etc. as shown in Section 1100, Battery of the Illustrated Parts Catalog. See Figure 1-1.

1.2 Reference Data

Table 1-1. Reference Data

Battery Crate Assembly Model	SMRX200F3 x 5, SMRX200F3 x 20, nickel-cadmium type
Battery Cells	The battery bank of each car is formed with four groups of five cells for a total of 20 cells connected in series. Each carset battery consists of 20 cells installed in a battery slide-out tray
Capacity	200 Ah
Terminals	One negative, one positive per block of five cells
Charging Voltage (20 cells, at battery terminals)	Single Rate: 28.5 V @ 1.47V/cell, 20ºC (68ºF)
Torque	(M12 terminal post; 12 mm / 19mm (1/2”) Top Nut) 15 ± 2 N.m (11± 1.5 ft.lb)
Electrolyte Type	An alkaline solution of KOH, LiOH and distilled water Designation: E10 (replacement)
Volume of Electrolyte (approximate, per cell)	1.87 liters (1.98 US quarts)

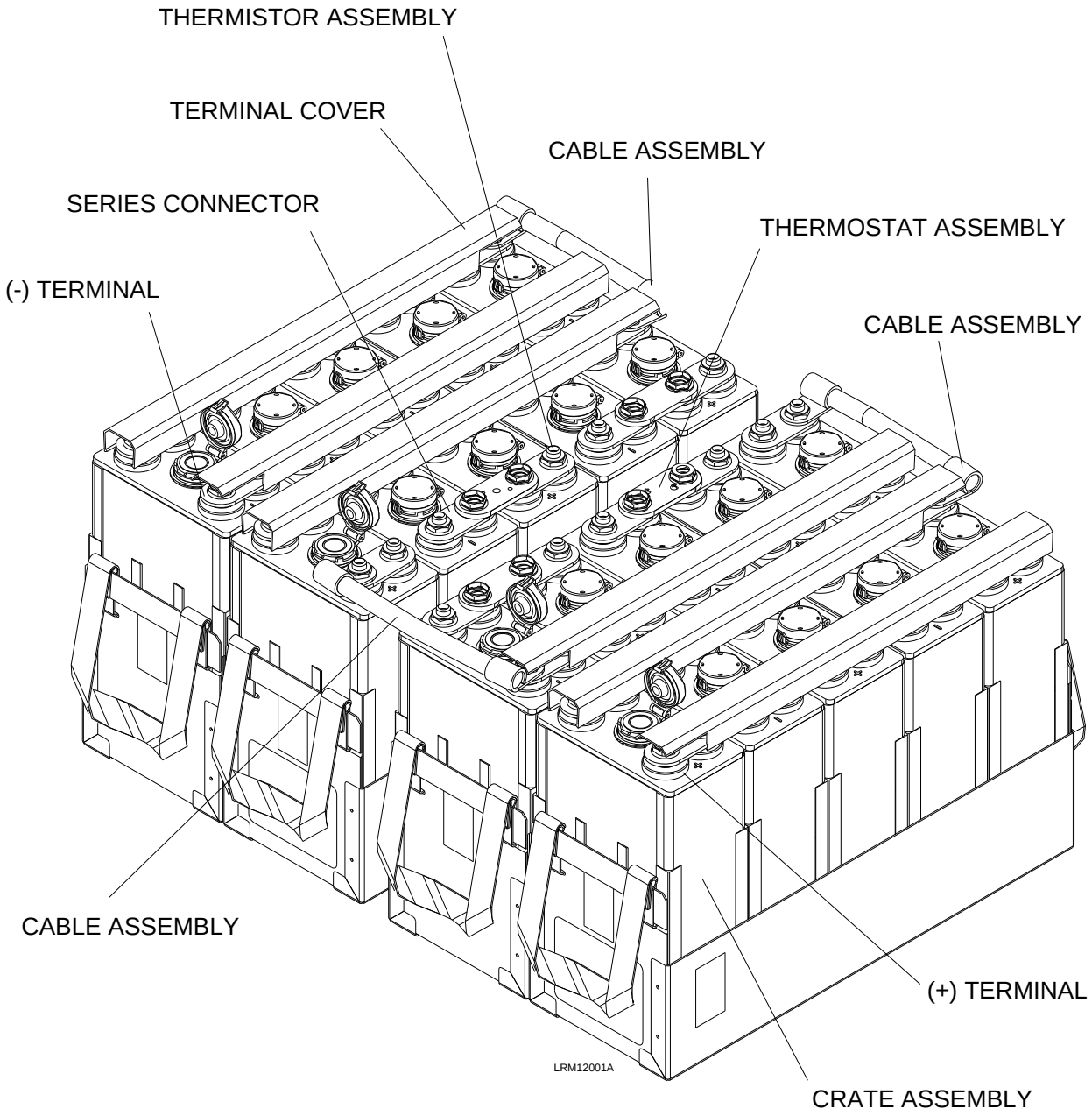

Figure 1-1: Battery Assembly

1.2.1 Electrodes

The electrodes/plates inside the nickel-cadmium cells are sintered positive and plastic bonded negative.

The positive active material is nickel hydroxide, and the negative active material is a cadmium-oxide mixture.

The sintered positive is obtained by chemical impregnation of nickel hydroxide into a porous nickel sinter coated thin steel strip that is previously perforated and nickel-plated.

The Plastic Bonded Electrode (PBE) is obtained by the coating of slurry consisting of cadmium oxide mixed with a plastic binder onto a nickel-plated thin perforated steel strip.

Each cell has plate stacks consisting of a number of positive and negative plates that are separated by a multilayer separator.

The plate stacks are bolted to the corresponding positive or negative terminal post(s).

1.2.2 Electrolyte

CAUTION

THE SULFURIC ACID USED IN LEAD ACID BATTERIES WILL RUIN A NICKEL-CADMIUM BATTERY.

DO NOT PUT SULFURIC ACID IN A NICKEL-CADMIUM CELL.

The alkaline electrolyte in a nickel-cadmium battery is a solution of potassium hydroxide (KOH), lithium hydroxide (LiOH) and distilled or deionized water. The electrolyte does not participate in the electrochemical reaction, which takes place in the battery cell, but only acts as an ion-carrying medium and its specific gravity remains relatively constant. Thus, a specific gravity reading from a nickel-cadmium cell does not give an indication as to its state of charge but may alter slightly due to plate and separator absorption.

1.2.3 Cell Container

CAUTION

DETERGENT SOLVENTS OR ANY OTHER CHEMICAL AGENTS ARE NOT TO BE USED UNLESS APPROVED BY SAFT. DIRECT SUNLIGHT AND HEAT MUST BE AVOIDED.

The cell container is made of a flame retardant transparent plastic named polysulfone. It is a strong, rigid plastic that resists most kinds of abuse and complies with NFPA 130.

Both sides of the container of each cell have two electrolyte level lines permanently stamped to aid when topping-up. The upper level line is the “MAX” and the lower is the “MIN” providing verification of levels.

Several cells are assembled together into stainless steel crates with nylon lifting handles.

1.2.4 Cell Vent Plug

WARNING

CELL VENT PLUG COVERS MUST REMAIN CLOSED AT ALL TIMES EXCEPT WHEN TOPPING-UP OR FILLING.

Each cell is equipped with a flip top flame arrester vent plug. The cell vent plug cover or cap, when closed, allows the escape of hydrogen and oxygen gases developed during the charging process. This cap prevents a flame or spark from entering the cell that could ignite this gas mixture contained internally in the upper cell compartment leading to an explosion.

1.2.5 Battery Assembly

The nickel-cadmium battery is assembled into the stainless steel battery slide-out tray within the battery compartment. In the rail/transit industry, a carset battery is made of several cells connected in series. Two or more cells are connected in series (from {+} to {-}) to form a battery. These series connections are achieved by using rigid intercell connectors made of nickel-plated copper and flexible cable connections/assemblies. The battery is normally equipped with a temperature sensor assembly mounted on an intercell connector or in a cable assembly lug. Refer to Chapter 6.0 for battery installation and removal.

1.2.6 Cell Identification

The cell type identification and the IEC 60623 standard designation that includes the capacity and performance are permanently printed on the cell container. The IEC 60623 designation for an SMRX200F3 cell type is KH200P for 200Ah and “H” high discharge rate performance. Each battery crate assembly has label(s) with the cell type identification and other battery crate assembly details.

The positive terminal has a red polarity washer and the negative terminal has a blue polarity washer. Both terminals can be further identified by the “+” and “-” raised symbols that are molded on the cell cover.

1.2.7 Date Code

The manufacturing date code, as part of the cell serial number, is hot stamped on top of the cell cover by month and year for the first four digits, e.g. 0514 for May 2014. The same manufacturing date code, month and year is also on the battery crate ID label.

CHAPTER 2.0

FUNCTIONAL DESCRIPTION

2.1 Introduction

Batteries are electrochemical systems used to supply energy for electrical and electronic equipment. Chemical energy stored in a battery is converted into electric current when the battery is discharged. This electric current is produced directly by chemical reactions that occur within the battery. The quantity of electric energy made available is a function of the inherent potential and efficiency of the electrochemical reactions, as well as the type and amount of active material in a battery.

2.2 Theory of Operation of Vented Cells

The nickel-cadmium cell is an electrochemical system in which the electrodes containing the active materials undergo changes in oxidation state without any change in physical state. These active materials are highly insoluble in alkaline electrolyte. They remain as solids and do not dissolve while undergoing changes in oxidation state. Because of this, the electrodes are long-lived, since no chemical mechanism that would cause the loss of active materials exists.

During cell charging and discharging operations, hydroxyl ions are transferred from the positive to the negative plates via the electrolyte. The alkaline solution, KOH (electrolyte), acts only as the transfer medium and does not participate in the electrochemical reaction. The role of the battery in the operations is passive rather than active, the electrolyte in a nickel-cadmium cell is never affected by the state of charge of the cell itself, but the specific gravity may alter slightly due to plate and separator absorption.

2.3 Rated Capacity

The international standard that specifies tests and requirements for vented nickel-cadmium cells is the IEC 60623.

The rated capacity of a vented nickel-cadmium cell is the quantity of electricity (C_5 in Ah) a single cell can deliver at the five (5) hour discharge rate to a final voltage of 1.0V at 20 ± 5ºC (68 ± 9°F). The conditions are that a discharged cell (≤ 1.0V) is charged at $0.2C_5A$ for 7 to 8 hours followed by a rest period of 1 - 4 hours, all performed at 20 ± 5ºC (68 ± 9°F). It shall then be discharged at $0.2C_5A$ for a minimum of five (5) hours at 20 ± 5ºC (68 ± 9°F). For a 200Ah battery the discharge/charge of 0.2 x 200 = 40A.

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CHAPTER 3.0

SPECIAL TOOLS AND MATERIALS

3.1 Introduction

When performing maintenance on the battery, use tools dedicated to Ni-Cd batteries with insulated handles.

CAUTION

SINCE TRACES OF SULFURIC ACID, AS USED IN LEAD ACID BATTERIES, CAN RUIN NICKEL-CADMIUM BATTERIES, ALL TOOLS INCLUDING WRENCHES, FILLING EQUIPMENT, ETC., MUST BE DEDICATED ONLY TO THE APPROPRIATE TECHNOLOGY OF THE BATTERY.

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CHAPTER 4.0

SCHEDULED MAINTENANCE TASKS

4.1 Introduction

This chapter provides scheduled maintenance tasks in the form of a quick reference table. A thorough visual inspection should be performed before proceeding. Obvious malfunctions from damage observed during the visual inspection are to be corrected.

4.2 Scheduled Maintenance Index

Table 4-1 is a scheduled maintenance index, which lists frequency and each maintenance task. The reference column indicates the section that details the procedures.

Table 4-1. Scheduled Maintenance Index

Maintenance Interval	Part Description	Scheduled Maintenance Task	Section 1100, Battery, Running Maintenance Manual, Section Reference
60,000 miles	Battery / Battery Compartment	Clean and visually inspect the battery and battery compartment. Replace if damaged or at end of life	5.2.1, 5.2.2 & 6.4
60,000 miles	Vent Plug Assembly	Visually inspect the Vent Plug Assemblies for proper operation. Replace if damaged.	5.2.3
60,000 miles	Terminal Nuts	Visually inspect that all terminal nuts are torqued properly. Replace if damaged.	5.3.1
60,000 miles	Battery Cable Connections	Visually inspect and replace any battery cable connections/assemblies that are frayed or damaged	5.3.1, 6.4
60,000 miles	Battery Metal Connections	Inspect and clean all exposed battery metal connections	5.3.2
60,000 miles	Electrolyte	Top up the Electrolyte Level	5.4
60,000 miles	Charging System	Check and adjust the Charging System	5.7
300,000 miles	Capacity Check	Perform a battery capacity check	5.6
After each Topping Up Operation	Battery	Visually inspect the Battery	5.2.1

NOTE: The cells should be topped-up with distilled water, (Section 5.4) when the electrolyte level is at the midway point of their electrolyte reserve, between the minimum (lower) and maximum (upper) levels. This method reduces the chances of having a cell run dry if it had been missed at the previous topping-up interval. By monitoring the water consumption once every 6 months for the first twelve months, the actual water consumption rate can be established more accurately for the environmental conditions and type of usage encountered.

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CHAPTER 5.0

ROUTINE AND PREVENTIVE MAINTENANCE

5.1 Introduction

This chapter provides inspection, cleaning and adjustment procedures for the battery components.

WARNING

ALWAYS REFER TO THE WARNINGS/CAUTIONS/NOTES FOR EACH SECTION IN THIS CHAPTER PRIOR TO BEGINNING ANY ACTIVITY.

NOTE: The regular car maintenance procedure should include the following battery maintenance operations:

- A “Routine and Preventive Maintenance Schedule” is supplied in Section 4.2,
- A “Discharge Test” record form (QC130) is supplied in Section 5.10,
- Refer to Section 7.2 for “Troubleshooting Chart” for further assistance.

5.2 Cleaning

CAUTION

USE CLEAN WATER TO CLEAN BATTERY SURFACE. NEVER USE DETERGENTS, SOLVENTS, OR OTHER CHEMICAL AGENTS SINCE THEY CAN DAMAGE THE PLASTIC BATTERY MATERIALS.

CELL VENT PLUG COVERS MUST REMAIN CLOSED AT ALL TIMES EXCEPT WHEN TOPPING-UP OR FILLING.

5.2.1 Keep Battery and Battery Compartment Dry

The battery must be kept clean and dry. This contributes to top performance and maximum service life. It also minimizes the risk of ground leakage currents and the risk of contaminating the electrolyte in the cells during the topping-up process. Clean and inspect the battery and battery compartment at least once every twelve months and the battery after each topping-up operation.

5.2.2 Clean With Water

CAUTION

THE COVERS OF THE VENT PLUGS MUST BE CLOSED AT ALL TIMES DURING CLEANING TO PREVENT TAP WATER FROM CONTAMINATING THE CELL ELECTROLYTE.

A clean gentle stream of water from a non-conductive hose is recommended to remove dust and dirt, and any grayish white deposits (refer to Section 5.5.2) from the battery and battery compartment. Do NOT use any pressured water for cleaning. Use clean water at room temperature and a soft non-metal brush and/or a lint-free cloth to aid in cleaning and drying. Dry the battery well using a dry clean lint-free cloth such as a wypall.

5.2.3 Cleaning Flame Arrester Vent Plugs

WARNING

PLUGGED VENT PLUGS OR VENT PLUG COVERS THAT DON'T OPEN OR CLOSE PROPERLY CAN LEAD TO PERSONAL INJURY AND/OR EQUIPMENT DAMAGE.

Dirty vent plugs should be rinsed in clean water. The vent plugs are of the bayonet-mount type and can be easily removed by turning them 1/4 turn counterclockwise. The cover on the vent plug assembly should be checked for proper operation. To open, the latch on the side should be pushed in and the vent cover should snap open (spring loaded). The vent cover should snap closed and remain closed after pushing it down. Replace any vent plugs that can't be cleaned and/or are damaged.

5.3 Connections and Sensor Assemblies

5.3.1 Check Yearly

CAUTION

DO NOT OVERTORQUE TERMINAL NUTS AS THIS CAN PERMANENTLY DAMAGE THE TERMINAL POST(S) OF THE CELL(S).

Once a year check that all terminal nuts are torqued properly. Torque to the value shown in Table 1-1. The terminal spring/wave washers must be underneath the top terminal nuts and flat. Look for hot spots revealing bad connections. Replace any battery cable connections/assemblies including the charge/discharge car power cables and any sensor assemblies if damaged or frayed. Refer to Table 4-1 for further checks.

5.3.2 Protective Coating

The battery terminals and the interconnecting hardware are protected with a thin layer of neutral Vaseline or Nox-Rust X-110 anti-corrosion protective coating before leaving the factory. After some time in service, or during removal and installation it may become necessary to clean and reapply a fresh thin coat on exposed battery metal connections. **Always apply after torque**.

5.4 Electrolyte Level

5.4.1 Electrolyte Level Adjustment/Topping-up

WARNING

ALWAYS REFER TO THE WARNINGS/CAUTIONS/NOTES FOR EACH SECTION IN THIS CHAPTER PRIOR TO BEGINNING ANY ACTIVITY.

ELECTROLYTE LEVELS BELOW THE MINIMUM (LOWER) LEVEL CAN HEAT THE CELL AND WITHIN TIME CAN LEAD TO A FIRE OR PERSONAL INJURY AND/OR EQUIPMENT DAMAGE.

DO NOT OVERFILL ABOVE THE MAXIMUM (UPPER) LEVEL; THAT COULD CAUSE AN OVERFLOW RESULTING IN GROUND LEAKAGE, WRONG SPECIFIC GRAVITY THAT CAN LEAD TO PERSONAL INJURY AND/OR EQUIPMENT DAMAGE.

VENT PLUG COVERS MUST BE CLOSED AFTER FILLING/TOPPING-UP. FAILURE TO DO SO CAN LEAD TO PERSONAL INJURY AND/OR EQUIPMENT DAMAGE.

CAUTION

NEVER USE ANY PIECE OF SERVICING EQUIPMENT SUCH AS FILLING EQUIPMENT, HYDROMETERS, CLEANING BRUSHES, ETC., THAT HAS BEEN USED TO SERVICE LEAD ACID BATTERIES. TRACES OF SULFURIC ACID, AS USED BY LEAD ACID BATTERIES, CAN RUIN NICKEL-CADMIUM BATTERIES.

NEVER USE SULFURIC ACID OR ACIDIFIED WATER WITH PH LOWER THAN 5 TO TOP-UP ELECTROLYTES. ACID CAN DESTROY THE BATTERY. ORDINARY TAP WATER CONTAINS IMPURITIES THAT CONTAMINATE THE ELECTROLYTE SOLUTION AND THUS AFFECT THE OPERATION OF THE CELLS. USE DISTILLED OR DEIONIZED WATER. IT MUST BE KEPT IN PLASTIC CONTAINERS AND BE LABELED ACCORDINGLY. THE IEC 60993 STANDARD DESCRIBES THE WATER QUALITY TO BE USED.

FAILURE TO USE THE TOPPING-UP EQUIPMENT PROPERLY CAN RESULT IN OVERFILLING OR UNDERFILLING OF BATTERY CELLS.

The cells should be topped-up with distilled water when the electrolyte level is at the midway point of their electrolyte reserve, between the minimum (lower) and maximum (upper) levels. This method reduces the chances of having a cell run dry if it had been missed at the previous topping-up interval.

The Celltopper Plus complete topping-up watering equipment comprises two basic units: a filling pistol and a watering cart equipment connected by a flexible hose. The filling pistol, which has a flow rate of 8 liters/min., shuts off at the right level when the correct spacer tube is used.

CAUTION

FAILURE TO USE EQUIPMENT PROPERLY CAN RESULT IN OVERFILLING OR UNDERFILLING OF BATTERY CELLS. THE FILLING PISTOL MUST HAVE THE CORRECT SPACER TUBE IDENTIFICATION LETTER MARKING AND MUST BE INSTALLED PROPERLY ON THE PROBE. THE SPACER TUBE MUST BE PUSHED COMPLETELY ON THE PROBE TOP SO THAT THERE IS NO VISIBLE SPACE BETWEEN THE SPACER TUBE AND THE PROBE TOP. REFER TO INSTRUCTIONS WITH CELLTOPPER PLUS EQUIPMENT FOR PROPER OPERATION AND FURTHER DETAILS.

Filling equipment such as the Celltopper Plus is available through Saft. These can save time and money when conducting maintenance.

When the above **Celltopper Plus filling equipment** is used, insert the end of the filling pistol with the probe through the hole of the open vent plug of a battery cell until the spacer tube sits on the open vent plug hole. Press and hold the handle until you feel the pistol stop dispensing distilled or deionized water. You will able to feel this in the handle. Release the handle. Remove probe from cell. Repeat for all cells and clean battery as per Section 5.2.

5.4.2 Water Loss

CAUTION

A BATTERY IN REVERSE POLARITY WILL CONSUME CONSIDERABLE AMOUNT OF WATER AND AN OVERFLOW MAY OCCUR CAUSING SHORTS, GROUNDING, MELTDOWN, AND/OR PERFORMANCE DETERIORATION.

All storage batteries lose water by electrolysis during charge and overcharge and also due to natural evaporation depending on the ambient temperature.

5.4.3 Too Much or Too Little Water Loss

Excessive water consumption may indicate too high a charging voltage (charging system not properly adjusted). Little water consumption may indicate that the battery is being inadequately charged.

5.4.4 Topping-up Frequency

NOTE: The water consumption varies due to several variables, i.e., charging voltage, battery temperature, the way the battery is used, age, etc.

To establish the water consumption rates on a new car, the electrolyte levels should be monitored once every six (6) months for the first 12 months of operation. The recommended value is per Table 4-1 in Section 4.2.

5.4.5 Water Type

Use **only** distilled or deionized water for topping-up.

5.4.6 Avoid Splashes

Avoid splashing water when topping-up. A wet battery can lead to ground faults and/or erratic operation. Refer to Section 5.2 for cleaning if this occurs.

5.4.7 Keep Vent Plug Covers Closed

For safety reasons and in order to minimize the chances of electrolyte contamination, keep the vent plug covers closed and locked, except when topping-up or filling.

5.4.8 Tools

WARNING

DO NOT LAY ANY TOOLS OR METAL PARTS ON TOP OF CELLS AS THIS ACTION MAY CAUSE AN ARC THAT CAN IGNITE THE GASES. TO PREVENT AN ARC OR SPARK WHEN THE BATTERIES ARE EITHER CONNECTED OR DISCONNECTED, THE CHARGING AND LOAD CIRCUITS MUST BE DISCONNECTED FIRST.

CAUTION

SINCE TRACES OF SULFURIC ACID, AS USED IN LEAD ACID BATTERIES, CAN RUIN NICKEL-CADMIUM BATTERIES, ALL TOOLS INCLUDING WRENCHES, FILLING EQUIPMENT, ETC., MUST BE DEDICATED ONLY TO THE APPROPRIATE TECHNOLOGY OF THE BATTERY.

Use tools dedicated to Ni-Cd batteries with insulated handles.

5.5 Electrolyte

5.5.1 Changing Electrolyte

Due to the sintered/PBE technology, **it is not necessary to change the electrolyte during the life of the cells.** In certain circumstances the electrolyte will require changing if contaminated water was used for topping-up possibly reducing the cell performance and capacity. If the contaminant were carbonate a change of electrolyte would recover the previous performances and capacity. However, changing electrolyte due to other contaminants in the cells would not recover the previous performances and capacity as they would cause permanent damage and reduce the life.

Prior to emptying the electrolyte from the cells, discharge at $0.2C_5A$ (40A) to below 0.8V for each and every cell. Refer to Table 1-1 for the type and quantity of Saft electrolyte required for each cell and contact Saft for assistance.

5.5.2 Grayish White Deposits

It's not abnormal to find small amounts of grayish white deposits around the top area of the cells. These deposits are potassium carbonate (K_2CO_3) which can form when the electrolyte (KOH) vapors combine with carbon dioxide (CO_2) in the air during the cells' natural gassing when on charge.

Small amounts of potassium carbonate are not a concern and can be easily cleaned per Section 5.2.

Excessive amounts of potassium carbonate could indicate issues such as a too high charge voltage, a leak, or an electrolyte overflow. In this case, contact Saft for further assistance.

5.6 Capacity Check

As part of the periodic maintenance operations, it is recommended to perform a battery capacity check every 5 years. While the routine maintenance operations are conducted on the cars, the removal of the battery from the car to the battery room of maintenance shop is required to perform a battery capacity check. Record test values on the "Discharge Test" record form (QC130) in Section 5.10.

WARNING

ALWAYS REFER TO THE WARNINGS/CAUTIONS/NOTES FOR EACH SECTION IN THIS CHAPTER PRIOR TO BEGINNING ANY ACTIVITY.

- **DURING CHARGING, GASES (OXYGEN AND HYDROGEN) ARE RELEASED BY THE BATTERY. DUE TO THIS GASSING EACH CELL WILL BE BUBBLING INTERNALLY. THE WORK AREA SHALL BE WELL VENTILATED TO PREVENT FROM AN EXPLOSIVE MIXTURE FORMING WHEN THE HYDROGEN CONCENTRATION EXCEEDS 4% VOLUME HYDROGEN TO AIR.**
- **WHEN REMOVING OR INSTALLING THE BATTERY, ALWAYS GET ASSISTANCE AND USE A SUITABLE LIFTING DEVICE TO AVOID PERSONAL INJURY. BEWARE OF POSSIBLE SHARP EDGES AND BURRS.**
- **VERIFY THAT ALL ELECTRICAL CONNECTIONS AND THEIR POLARITIES ARE MADE CORRECTLY INCLUDING CHARGE/DISCHARGE CAR POWER CABLES.**

The following procedure must be followed to check the battery capacity (refer to Section 2.3 for the description of rated capacity and Table 1-1 for the actual rated capacity of a new battery). A capacity test is easier to be controlled and performed in a battery room of maintenance shop with the appropriate tools and equipment.

1. Remove battery from battery slide-out tray or battery together with battery slide-out tray from battery compartment (if applicable) as per Chapter 6.0.

2. Take battery (with battery slide-out tray if applicable) to battery room of maintenance shop and place on a flat bench keeping the battery level.

3. Reassemble battery per Chapter 6.0. (If battery together with battery slide-out tray is removed from car then skip to step 4).

4. Top-up battery. Refer to Section 5.4.

5. Discharge at $0.2C_5A$ (40A) down to below 0.8V per cell. This will allow all cells to be approximately the same state of charge. Reversing polarities of cells will not damage them but will consume more water and generate more gases (oxygen and hydrogen).

6. Charge using constant current charging at $0.2C_5A$ (40A) for 8 hours.

7. Allow battery to rest for 1 to 4 hours.

8. Discharge at $0.2C_5A$ (40A) to 1.0V/cell. Record voltage of each cell and overall battery every hour and every half-hour after the first three hours on QC130 “Discharge Test” record form in Section 5.10. If an Ah counter is used, record Ah discharged.

9. Remove battery crate assemblies from battery slide-out tray (if applicable). Remove any cell(s) that are not acceptable and install replacement discharged cells.

10. Install and assemble battery back in battery slide-out tray per Chapter 6.0. (If battery together with battery slide-out tray was not removed from car then skip to step 11).

11. Commission battery (charge, discharge, charge, topping-up, and cleaning).

12. Place battery or battery together with battery slide-out tray (if applicable) back in car and place into service.

5.7 Charging System

CAUTION

HIGH WATER CONSUMPTION REQUIRES IMMEDIATE CHECK OF THE CHARGING SYSTEM TO PREVENT PERMANENT DAMAGE TO THE BATTERY. ALSO, CHECK OPEN CIRCUIT (NO CHARGE/DISCHARGE) CELL VOLTAGES FOR SHORTED CELLS (0 VDC) THAT MAY ALSO HAVE CONSUMED VERY LITTLE OR NO WATER.

Check the Metro Maintenance Shop charging system at least once yearly to ensure that it is operating within specified limits.

Fault conditions in the battery may be indicative of a charger malfunction.

i.e.:	Low water consumption	=	Low charging system output voltage
	High water consumption	=	High charging system output voltage
	Insufficient battery capacity	=	Incomplete recharge

5.8 Maintenance Tips

There are basically three (3) considerations required to maintain this battery:

1. Maintain the electrolyte levels.

2. Ensure that battery is being properly charged.

3. Maintain battery in a clean and dry condition.

5.9 Maintenance Record Chart

CAR NO:	TOTAL CHARGING VOLTAGE AT BATTERY TERMINALS:

Note:
- **If the cells are not numbered, always consider the cell with the positive car cable terminal as cell No. 1.**
- **O.C.V. is the open circuit voltage measured without charge or discharge and 1 hour after the end of charge when it is stabilized.**

CELL	VOLTAGE (NO LOAD)	ELECTROLYTE LEVEL	WATER ADDED YES	WATER ADDED NO	COMMENTS
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					

CELL	VOLTAGE (NO LOAD)	ELECTROLYTE LEVEL	WATER ADDED YES	WATER ADDED NO	COMMENTS
14					
15					
16					
17					
18					
19					
20					

CELL TEMP. (MIDDLE OF BATTERY)	TORQUE CHECKED: (ALL CELLS)	TOTAL WATER ADDED:	BATTERY CLEANING COMPLETED:
☐ °C _____ ☐ °F	☐ Yes ☐ No	QTY: _____ ☐ liter(s) ☐ quart(s)	☐ Yes ☐ No
GENERAL COMMENTS:	SERVICE DATE:	SERVICED BY:	

5.10 Discharge Test

DISCHARGE TEST - ESSAI DE DECHARGE

QC 130
REV. 2 94-06-22

REF. SPEC. NR.:
NORME REF. NO.: ____________

DATE:
DATE: ____________

TEST FOLLOWING:
TEST SUIVANT:

TYPE OF CELLS: SMRX200F3
TYPE D'ELEMENT: ____________

CAPACITY: 200 Ah
CAPACITE:

QUANTITY: ____________
QUANTITE:

ORDER NR.:
COMMANDE NO.:

PREVIOUS OPERATION
OPERATIONS DEJA EFFECTUEES

CHARGING TIME:____ H AT ______A : DISCHARGING AT:____A
CHARGE DE: A DECHARGE A:

CHARGING TIME:____ H AT ______A : DISCHARGING AT:____A
CHARGE DE: A DECHARGE A:

CHARGING TIME:____ H AT ______A : DISCHARGING AT:____A
CHARGE DE: A DECHARGE A:

START END
DEBUT FIN
AMBIENT TEMP. : °C °C
TEMP. AMBIANTE: ________ ________

DISCHARGE AT: ________AMP.
DECHARGE A:
AFTER
________ APRES

CHARGING
TIME: HRS.@ AMP.
CHARGE DE: HEURES A

PREVIOUS ELECTROLYTE CHANGES
CHANGEMENTS D'ELECTROLYTE EFFECTUES

1ST ELECTROLYTE USED: NR. S.G.
1ER ELECTROLYTE NO. G.R.
UTILISE:

2ND ELECTROLYTE USED: NR. S.G.
2EME ELECTROLYTE NO. G.R.
UTILISE:

HOURS HEURES	DURAT. TEMPS	COUNTER COMPTEUR	Ah Ah	TEMP. TEMP.	CELL TERMINAL VOLTAGE - TENSION AUX BORNES DES ELEMENTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

PERFORMED BY:
EFFECTUE PAR:

TEST WITNESSED IN PRESENCE OF:
ESSAIS EFFECTUE EN PRESENCE DE:

CUSTOMER ACCEPTANCE:
ACCEPTE PAR CLIENT:

CHAPTER 6.0

COMPONENT REMOVAL AND INSTALLATION

6.1 Introduction

This chapter provides removal and installation procedures for the battery.

6.2 Safety Information

WARNING

ALWAYS REFER TO THE WARNINGS/CAUTIONS/NOTES FOR EACH SECTION IN THIS CHAPTER PRIOR TO BEGINNING ANY ACTIVITY.

DURING CHARGING, GASES (OXYGEN AND HYDROGEN) ARE RELEASED BY THE BATTERY. DUE TO THIS GASSING EACH CELL WILL BE BUBBLING INTERNALLY. THE WORK AREA SHALL BE WELL VENTILATED TO PREVENT FROM AN EXPLOSIVE MIXTURE FORMING WHEN THE HYDROGEN CONCENTRATION EXCEEDS 4% VOLUME HYDROGEN TO AIR.

WHEN REMOVING OR INSTALLING THE BATTERY, ALWAYS GET ASSISTANCE AND USE A SUITABLE LIFTING DEVICE TO AVOID PERSONAL INJURY. BEWARE OF POSSIBLE SHARP EDGES AND BURRS.

VERIFY THAT ALL ELECTRICAL CONNECTIONS AND THEIR POLARITIES ARE MADE CORRECTLY INCLUDING CHARGE/DISCHARGE CAR POWER CABLES DURING INSTALLATION.

NEVER CHARGE THE BATTERY WITH THE PLASTIC TRANSPORT SEAL(S) IN PLACE UNDER THE VENT PLUG COVER, AS THIS IS DANGEROUS AND CAN CAUSE BODILY INJURY AND PERMANENT DAMAGE TO THE BATTERIES.

CAUTION

IF A DEFECT IS FOUND ON ANY CELL, THE ENTIRE BATTERY (NOT INDIVIDUAL CELLS OR BATTERY CRATE ASSEMBLIES) WITH THE BATTERY SLIDE-OUT TRAY (IF APPLICABLE) MUST BE REMOVED FROM THE CAR AND SENT TO BATTERY ROOM OF MAINTENANCE SHOP.

BEFORE REPLACING ONE OR MORE CELLS FROM A BATTERY IN SERVICE IT IS RECOMMENDED TO DISCHARGE THE ENTIRE BATTERY WITH CAR LOADS OR LOAD BANK USING A 0.2C5A (40A) DISCHARGE CURRENT TO 1.0V OR LESS FOR EACH AND EVERY CELL.

CAUTION

WHEN CELL REPLACEMENT IS NECESSARY, IT IS RECOMMENDED TO REPLACE WITH CELL(S) OR BATTERY CRATE ASSEMBLIES HAVING SIMILAR SERVICE LIFE, AGE, AND CAPACITY AS THE REST OF THE BATTERY. NEW CELLS OR BATTERY CRATE ASSEMBLIES SHALL BE PART OF NEW BATTERIES.

NEVER MIX CHARGED AND DISCHARGED CELLS OR BATTERY CRATE ASSEMBLIES IN THE SAME CARSET BATTERY.

AFTER REPLACING ONE OR MORE BATTERY CRATE ASSEMBLIES IN A BATTERY OUT OF SERVICE, IT IS RECOMMENDED TO COMMISSION THE ENTIRE BATTERY INCLUDING THE REPLACEMENT BATTERY CRATE ASSEMBLIES.

ALWAYS REFER TO THE DRAWING(S) AND TORQUE VALUES FOR PROPER CONNECTIONS.

ALL CONTACT SURFACES INCLUDING THE SLIDE-OUT TRAY AND THE COMPARTMENT MUST BE CLEAN AND DRY BEFORE THE BATTERY IS CONNECTED TO THE CAR POWER.

BATTERY CRATE ASSEMBLIES MUST BE INSTALLED CAREFULLY INTO THE BATTERY SLIDE-OUT TRAY WITHOUT DAMAGING ANY EXTERNAL ATTACHMENTS OR PROJECTIONS AND MUST BE MECHANICALLY SUPPORTED TO AVOID ANY MOVEMENT IN ANY DIRECTION.

USE ONLY DISTILLED OR DEIONIZED WATER FOR TOPPING-UP.

AFTER REMOVAL OF NUTS, AND WASHERS FROM THE BATTERY THEY MUST BE REINSTALLED LOOSELY TO AVOID LOSING THEM.

WHEN THE BATTERY SLIDE-OUT TRAY IS OPERATED, THE FLEXIBLE CAR POWER CABLE CONNECTIONS/ASSEMBLIES MUST NOT CATCH, KINK OR RUB ON THE BATTERY OR ANY BATTERY COMPARTMENT COMPONENTS.

NOTE: The battery consists of cells connected in series with rigid intercell connectors and flexible cable connections/assemblies. The cells' positive terminals are identified with red polarity washers and the negative terminals have blue polarity washers. Both terminals can be further identified by the "+" and "-" raised symbols that are molded on the cell cover.

All battery hardware such as nuts, washers, rigid connectors, and cable lugs are nickel-plated and metric sized. All replacement hardware must be Saft supplied.

6.3 Battery Overview

The battery must be mounted firmly in the battery slide-out tray. External rigid connections within the battery crate assembly are factory installed. The positive terminals are identified with red polarity washers and the negative terminals have blue polarity washers. Both terminals can be further identified by the "+" and "-" raised symbols that are molded on the cell cover. Intercrate flexible cable connections/assemblies and other components as identified by the battery layout, Figure 6-1 are provided as original equipment and can be ordered as parts. All contact surfaces including the battery slide-out tray and battery compartment must be clean and dry.

6.4 Inspecting Battery in Battery Slide-Out Tray

1. Ensure battery breaker is in OFF position (de-energized) so that during inspection the battery will be completely isolated from car loads and charging system.

2. Pull out the battery slide-out tray from the battery compartment.

3. Inspect terminal covers from top of battery connections to ensure they are securely mounted.

4. Inspect flexible intercrate cable connections/assemblies, in series (from "+" to "-" terminals) for each row of battery crate assemblies as shown in Figure 1-1. Re-torque if necessary accordingly to value shown in Table 1-1.

5. Inspect thermostat/thermistor in middle of battery as shown in Figure 1-1 to ensure it is securely mounted.

6. Apply a thin coat of neutral Vaseline or Nox-Rust anti-corrosion protective coating on exposed battery metal connections where not already present such as where the flexible cable assemblies are connected.

7. Inspect all terminal covers along top of all exposed connections to ensure they are secure.

8. Connect battery to power with breaker to ON position (energized).

9. Check charging voltage setting at battery terminals at end of charge. If the charging was performed on the vehicle this voltage should be 28.5 ± 0.5 VDC. If the charging was performed outside the vehicle the voltage should be 29.4 ± 0.5 VDC. If the charging was performed outside the vehicle adjust accordingly, if required, as per instructions in charging system manual.

10. Re-install battery into slide-out tray and push the battery slide-out tray into in the battery box compartment.

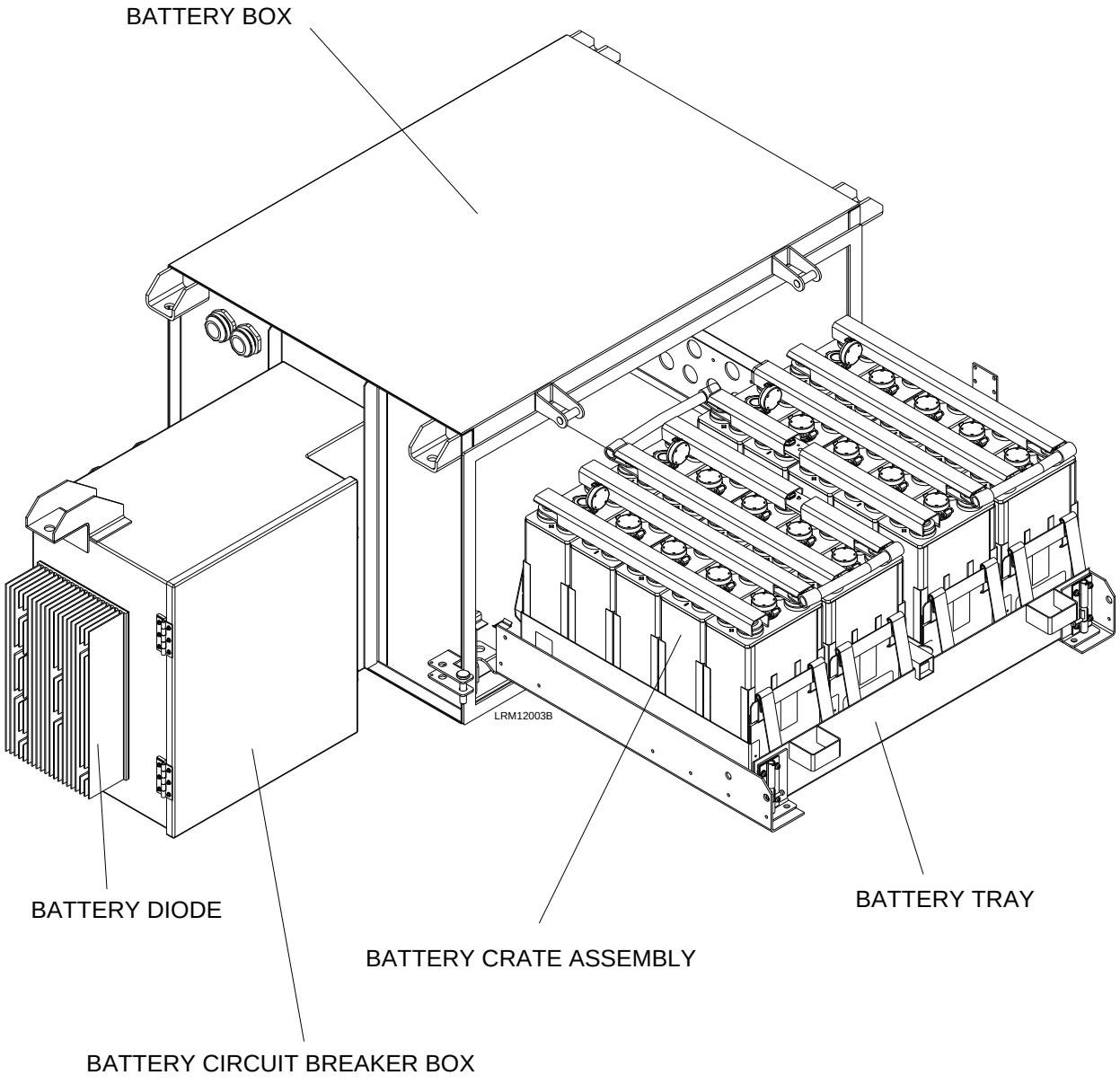

Figure 6-1: Battery Box Assembly

CHAPTER 7.0

TROUBLESHOOTING

7.1 Introduction

The following troubleshooting chart is provided to help the operator, maintenance, and battery shop personnel in establishing a guide to diagnose a battery malfunction. This chart correlates the symptom(s) with the probable cause(s) and provides recommendation(s) of corrective action(s) to be undertaken to return the battery to a normal behavior.

WARNING

REFER TO THE WARNINGS / CAUTIONS / NOTES IN CHAPTERS 5.0 AND 6.0 BEFORE ATTEMPTING ANY OF THE FOLLOWING TROUBLESHOOTING PROCEDURES.

7.2 Troubleshooting Chart

Table 7-1. Troubleshooting Chart

Symptom	Probable Cause	Corrective Action
1. Battery does not supply emergency loads as required. (Also refer to 12 below)	1a. Battery has been discharged and not recharged.	1a. Charge battery on the car continuously for at least 8 hours prior to train departure.
	1b. Loads (APS, NVR, and Emergency Lighting) have been left on battery overnight, after charging system has been shut off.	1b. Charge battery on the car continuously for at least 8 hours prior to train departure.
	1c. Ground leakage due to a wet and/or dirty battery.	1c. Clean and dry battery and battery compartment as per Section 5.2. Charge battery on car continuously for at least 8 hours prior to train departure.
	1d. Electrolyte levels have been allowed to fall below minimum level causing exposure of plates and active material.	1d. Top-up battery with water to the maximum level and charge on the car to attempt restoration of battery. Refer to Section 5.4. A capacity check per Section 5.6 can be performed.
	1e. Cracked or leaking cell(s).	1e. Replace battery and send to the battery shop for replacement of cracked or leaking cell(s), as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	1f. Charge voltage too low.	1f. Recalibrate charging system output settings as per Table 1-1 and Section 5.7. Also, refer to the charging system manual.
	1g. Unequal cell voltages.	1g. All cells should be within ±0.03V from average value when in open circuit. If not, check all connections as per Section 5.3 and commission battery per Section 1100 of the HRM. Contact Saft for further details if probable cause still exists.

Table 7-1. Troubleshooting Chart (cont'd.)

Symptom	Probable Cause	Corrective Action
1. Battery does not supply emergency loads as required. (Also refer to 12 below) (cont'd.)	1h. Cell(s) below 1.25 volts.	1h. If any cell(s) are below 1.25V while in charge for some time, or in open circuit, then commission the battery per Section 1100 of the HRM.
	1i. Cell reversal and/or discharged cell(s) has been mixed with charged cells.	1i. Check for correct polarity connections. Conduct commissioning on the entire battery per Section 1100 of the HRM. If battery is dirty, clean and dry battery and battery compartment as per Section 5.2. Contact Saft for further details if probable cause still exists.
	1j. Check electrolyte specific gravity in cell(s).	1j. Replace electrolyte as per Section 5.5.1. Contact Saft for further info.
2. Erratic Battery Behavior.	2a. Loose connections within battery or between battery and load or charging system.	2a. Replace damaged connection(s) as per Chapter 6.0. Apply torque values to all connection nuts as per Section 5.3. Charge battery on the car for at least 8 hours prior to train departure.
	2b. Wrong polarity connections.	2b. Check for proper polarity connections. Refer to Section 1.2.6.
	2c. Empty cell.	2c. Check if cell is empty because of leakage. If so, remove or short-circuit that cell and use the battery with one less cell until replacement battery is made. If cell is part of battery crate assembly with more than 1 cell, do not remove battery crate assembly, just short circuit cell until replacement battery is available. Replace battery and send to battery shop for replacement of defective cell(s)/battery crate assemblies as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean battery and battery compartment as per Section 5.2. Note: Electrolyte levels must be closely monitored while battery has one less cell.
	2d. Faulty charging system.	2d. Check charging system. Refer to Section 5.7. Charge battery on car continuously for at least 8 hours prior to train departure.
3. Excessive Water Consumption.	3a. Charge voltage too high.	3a. Switch off the battery breaker. Check APS output per Section 0900 of the RMM. Check charging system. Refer to Section 5.7 and charging system manual. Top-up electrolyte levels as per Section 5.4. If battery is dirty, clean and dry battery and battery compartment as per Section 5.2.
	3b. Shorted cell(s), causing a higher charging voltage on rest of cells in battery.	3b. Replace battery and send to battery shop for replacement of defective cell(s)/battery crate assemblies as per Chapter 6.0. Commission battery per Section 1100 of the HRM. If battery is dirty, clean and dry battery and battery compartment as per Section 5.2.
	3c. Small leak or cracks/cell(s) dry out.	3c. Check for wetness in battery compartment and/or check with a voltmeter what part(s) of battery has lowest potential to ground, and then follow 1e above.
	3d. Elevated outside temperature and/or no compensation on charging voltage.	3d. Top-up electrolyte levels as per Section 5.4. Check charging system per Section 5.7 and charging system manual.

Table 7-1. Troubleshooting Chart (cont'd.)

Symptom	Probable Cause	Corrective Action
4. Little or No Water Consumption.	4a. Charge voltage too low.	4a. Recalibrate charging system as per Table 1-1 and Section 5.7.
	4b. Shorted cell.	4b. A cell with partial or complete short-circuit will consume less water than others. Let cell remain in circuit until a replacement battery is made available. Topping-up remaining cells more frequently. Replace battery and send to battery shop for replacement of defective cell(s)/battery crate assemblies as per Chapter 6.0. Commission battery per Section 1100 of the HRM.
5. Ground Fault Indication.	5a. Small leaks or cracks/cell(s) dry out.	5a. Check for wetness in battery compartment and/or check with a voltmeter what part(s) or battery has lowest potential to ground, and then follow 1e. above.
	5b. Battery wet from overfilling.	5b. If no overflow has occurred, clean and dry battery and battery compartment as per Section 5.2 and charge on car continuously for 8 hours prior to train departure. If overflow occurred, replace battery as per Chapter 6.0 and send to battery shop for checking and possibly replacing electrolyte as per Section 5.5.1. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	5c. Equipment other than battery can be causing fault.	5c. Check charging system, isolate loads on car, and if required, isolate cars in order to locate ground.
6. Continuous Heavy Gassing.	6a. Charging remains at high rate and does not return to float charge or charging system has gone higher than specified limits.	6a. Check charging system. Refer to Section 5.7 and charging system manual.
	6b. Cell(s) have wrong polarity connections and/or discharged cell(s) has been mixed with charged cells.	6b. Check for correct polarity connections. Conduct commissioning on entire battery per Section 1100 of the HRM. If battery is dirty, clean and dry battery and battery compartment as per Section 5.2. Contact Saft for further details if probable cause still exists.
7. Electrolyte Leakage.	7a. Ruptured cell(s) (cracked or leaking).	7a. Replace battery and send to battery shop for replacement of cracked or leaking cell(s), as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	7b. Battery wet from overfilling.	7b. If no overflow has occurred, clean and dry battery and battery compartment as per Section 5.2 and charge on car continuously for 8 hours prior to train departure. If overflow occurred, replace battery as per Chapter 6.0 and send to battery shop for checking and possibly replacing electrolyte as per Section 5.5.1. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.

Table 7-1. Troubleshooting Chart (cont'd.)

Symptom	Probable Cause	Corrective Action
8. Corrosion of Equipment or Metallic Parts Close to Battery.	8a. Ruptured cell(s) and/or electrolyte leakage.	8a. Replace battery and send to battery shop for replacement of cracked or leaking cell(s), as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	8b. Hydrogen ignition outside or inside cell(s).	8b. Replace battery as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
9. Short-Circuited Battery.	9a. Ruptured cell(s) and/or electrolyte leakage.	9a. Replace battery and send to battery shop for replacement of cracked or leaking cell(s), as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	9b. Dirty cell(s), foreign material between cells/connections.	9b. Clean and dry battery and battery compartment as per Section 5.2 and charge on car continuously for 8 hours prior to train departure.
	9c. Mechanical contact between cell(s) and/or battery compartment.	9c. Check battery connections as per Section 5.3. Replace any damaged cable assemblies, cell(s), and battery components as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
10. Short-Circuited Cell(s).	10a. Metallization, perforation, or oxidation of separators.	10a. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	10b. Hydrogen ignition.	10b. Refer to 14 below.
	10c. Cell(s) dry out.	10c. Check charging system. Refer to Section 5.7 and charging system manual. Check cell(s) for cracks/ leaks and check for wetness in battery compartment. Top-up electrolyte levels as per Section 5.4. If cracks/leaks are found, replace battery and send to battery shop for replacement of damaged cell(s) as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	10d. Cell(s) aging/end of life.	10d. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	10e. Metallic particles inside cell(s).	10e. Replace battery and send to battery shop for replacement of cell(s) as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	10f. Improper water used	10f. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2. Also refer to Section 5.4.5 for type of water.

Table 7-1. Troubleshooting Chart (cont'd.)

Symptom	Probable Cause	Corrective Action
11. Cell Internal Resistance Increasing.	11a. Rupture of several internal cell connections.	11a. Check for correct polarity connections. Replace battery and send to battery shop for replacement of cell(s) as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
12. Reduced Peak Performance; Reduced Back-Up Time. (Also refer to 1 above)	12a. Rupture of several internal cell connections.	12a. Check for correct polarity connections. Replace battery and send to battery shop for replacement of cell(s) as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12b. Ruptured cell(s), connection(s).	12b. Replace battery and send to battery shop for replacement of cell(s) as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12c. Metallization, perforation, or oxidation of separators.	12c. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12d. Several sheets of separator missing.	12d. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Cclean and dry battery and battery compartment as per Section 5.2.
	12e. Hydrogen ignition outside cell(s) due to presence of flame or spark.	12e. Check battery connections as per Section 5.3. Check for wetness in battery compartment and/or check with a voltmeter what part(s) of battery has lowest potential to ground. Replace damaged components and battery (if any damaged/leaking cells) and send to battery shop as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12f. Hydrogen ignition inside cell(s) due to absence of flame arrester vent or open vent and presence of flame or spark.	12f. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12g. Open circuit due to cell(s) dry out or internal corrosion due to use of acid or other water contaminants.	12g. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2. Also refer to Section 5.4.5 for type of water.
	12h. Open circuit due to damaged or loose connection(s) between cells or crate battery crate assemblies.	12h. Replace damaged connection(s) as per Chapter 6.0. Apply torque values to all connection nuts as per Section 5.3. Charge battery on car for at least 8 hours prior to train departure.

Table 7-1. Troubleshooting Chart (cont'd.)

Symptom	Probable Cause	Corrective Action
12. Reduced Peak Performance; Reduced Back-Up Time. (Also refer to 1 above) (cont'd.)	12i. Shorted cell(s) and/or metallic particles inside cell(s).	12i. A cell(s) with partial or complete short-circuit will consume less or no water than others. Let cell(s) remain in circuit until a replacement battery is made available. Topping-up remaining cells may be more frequent. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12j. Overflow/overfilling of electrolyte level(s) causing short(s).	12j. Replace battery as per Chapter 6.0 and send to battery shop for checking and possibly replacing electrolyte as per Section 5.5.1. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12k. Mechanical contact between cell(s) and/or battery compartment.	12k. Check battery connections as per Section 5.3. Replace any damaged cable assemblies, battery components, and battery (if any cell is damaged) and send to battery shop as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12l. Battery not well charged and/or temperature compensation lacking.	12l. Check charging system. Refer to Section 5.7. Charge battery on car continuously for at least 8 hours prior to train departure.
	12m. Electrolyte missing/ruptured cell(s) and/or electrolyte leakage.	12m. Replace battery and send to battery shop for replacement of cracked or leaking cell(s), as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	12n. Cell(s)/battery aging or end of life.	12n. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
13. Open Circuit	13a. Ruptured cell(s) or connection(s).	13a. Replace damaged connection(s) and/or battery send to battery shop as per Chapter 6.0. Apply torque values to all connection nuts as per Section 5.3. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	13b. Loose connection(s).	13b. Apply torque values to all connection nuts as per Section 5.3. Charge battery on car for at least 8 hours prior to train departure.
	13c. Cell(s) dry out.	13c. Check charging system. Refer to Section 5.7 and charging system manual. Check cell(s) for cracks/ leaks and check for wetness in battery compartment. Top-up electrolyte levels as per Section 5.4. If cracks/leaks are found, replace battery and send to battery shop for replacement of damaged cell(s) as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.

Table 7-1. Troubleshooting Chart (cont'd.)

Symptom	Probable Cause	Corrective Action
13. Open Circuit (cont'.d)	13d. Internal corrosion due to use of acid or other water contaminants.	13d. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2. Also refer to Section 5.4.5 for type of water.
14. Hydrogen Ignition with Presence of Flame or Spark.	14a. Loose connections.	14a. Apply torque values to all connection nuts as per Section 5.3. Charge battery on car for at least 8 hours prior to train departure.
	14b. Shorting of connection(s)/grounding. Mechanical contact between cell(s) and/or battery compartment.	14b. Check battery connections as per Section 5.3. Check for wetness in battery compartment and/or check with a voltmeter what part(s) of battery has lowest potential to ground. Replace damaged components, and battery (if any damaged/leaking cells) and send to battery shop as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	14c. Damaged cable assemblies.	14c. Check battery connections as per Section 5.3. Replace any damaged cable assemblies. Charge battery on car for at least 8 hours prior to train departure.
	14d. Incorrectly connected cell(s)/battery and/or reversed cell(s).	14d. Replace battery if damaged and send to battery shop per Chapter 6.0. Check for correct polarity connections. Conduct commissioning on entire battery per Section 1100 of the HRM. If battery is dirty, clean and dry battery and battery compartment as per Section 5.2. Contact Saft for further details if probable cause still exists.
	14e. Charging voltage too high or charging system malfunction.	14e. Check charging system. Refer to Section 5.7 and charging system manual. Top-up electrolyte levels as per Section 5.4. Replace battery and/or components and send to battery shop if damaged as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	14f. Poor or blocked battery compartment ventilation.	14f. Increase ventilation and/or clean battery compartment. Replace battery and/or components and send to battery shop if damaged as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	14g. Overflow/overfilling of electrolyte level(s) causing short(s).	14g. Replace battery as per Chapter 6.0 and send to battery shop for checking and possibly replacing electrolyte as per Section 5.5.1. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	14h. Cell(s) damaged and/or short-circuited, and/or in open circuit.	14h. Replace battery and/or components and send to battery shop if damaged as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.

Table 7-1. Troubleshooting Chart (cont'd.)

Symptom	Probable Cause	Corrective Action
14. Hydrogen Ignition with Presence of Flame or Spark. (cont'd.)	14i. Flame arrester vent missing, vent damaged, or open vent.	14i. Replace battery and/or components and send to battery shop if damaged as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	14j. Metallic jewelry, tools/metal parts, or clothing with metal parts in contact with battery. Terminal covers missing.	14j. Always refer to Warnings/Cautions/Notes in each section prior to working with batteries. Replace battery and/or components and send to battery shop if damaged as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
15. Cell Dry Out	15a. Ruptured cell(s) (cracked or leaking).	15a. Check charging system. Refer to Section 5.7 and charging system manual. Check cell(s) for cracks/leaks and check for wetness in battery compartment. Top-up electrolyte levels as per Section 5.4. If cracks/leaks are found, replace battery and send to battery shop for replacement of damaged cell(s) as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	15b. Lack of topping-up electrolyte levels.	15b. Replace battery as per Chapter 6.0. Commission replacement battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2. Also refer to Section 5.4 on electrolyte levels.
	15c. Charging voltage too high or charging system malfunction.	15c. Check charging system. Refer to Section 5.7 and charging system manual. Replace battery and send to battery shop as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	15d. Elevated outside temperature and/or no compensation on charging voltage.	15d. Check charging system. Refer to Section 5.7 and charging system manual. Replace battery and send to battery shop as per Chapter 6.0. Commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	15e. Poor and/or obstructed ventilation in battery compartment.	15e. Increase ventilation and/or clean battery compartment. Replace battery and/or components and send to battery shop if damaged as per Chapter 6.0 and commission battery per Section 1100 of the HRM. Clean and dry battery and battery compartment as per Section 5.2.
	15f. Cell(s) in short-circuit and/or end of life.	15f. Replace battery as per Chapter 6.0. Commission replacement battery and clean and dry battery and battery compartment as per Section 5.2.

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