Eskom	Task Manual	Technology

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Content

Figures

1. Introduction

This Task manual was compiled from the analysis that was done on critical tasks performed during Battery Commissioning. It is critical to ensure that identified risks and hazards associated to these tasks are effectively addressed or remedied to prevent/avoid damage to equipment or injury to staff. Figure 1 and Figure 2 show an exploded view of a vented flooded lead acid (VFLA) cell and nickel cadmium cell, respectively.

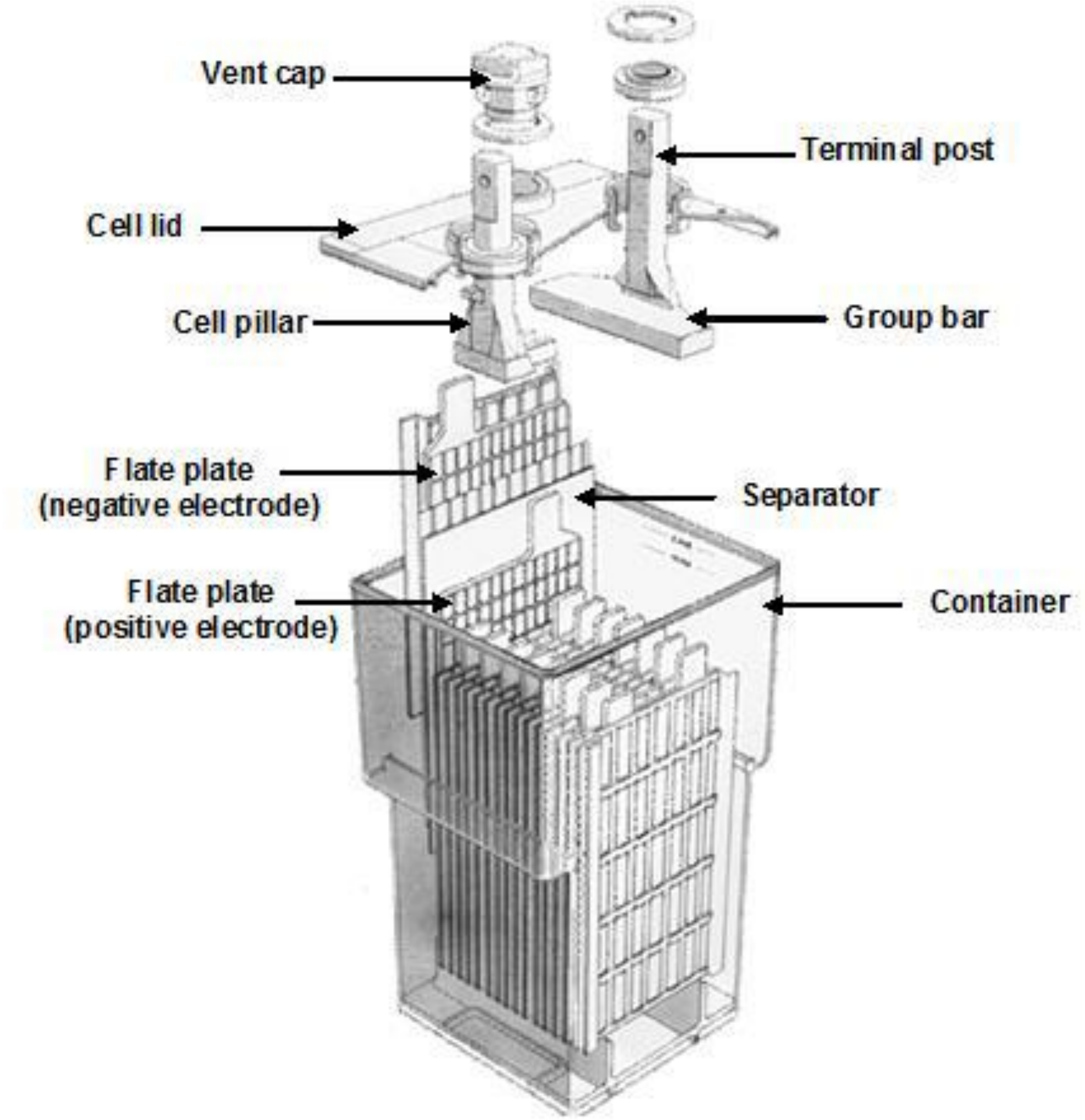


Figure 1: Exploded View of a VFLA Cell

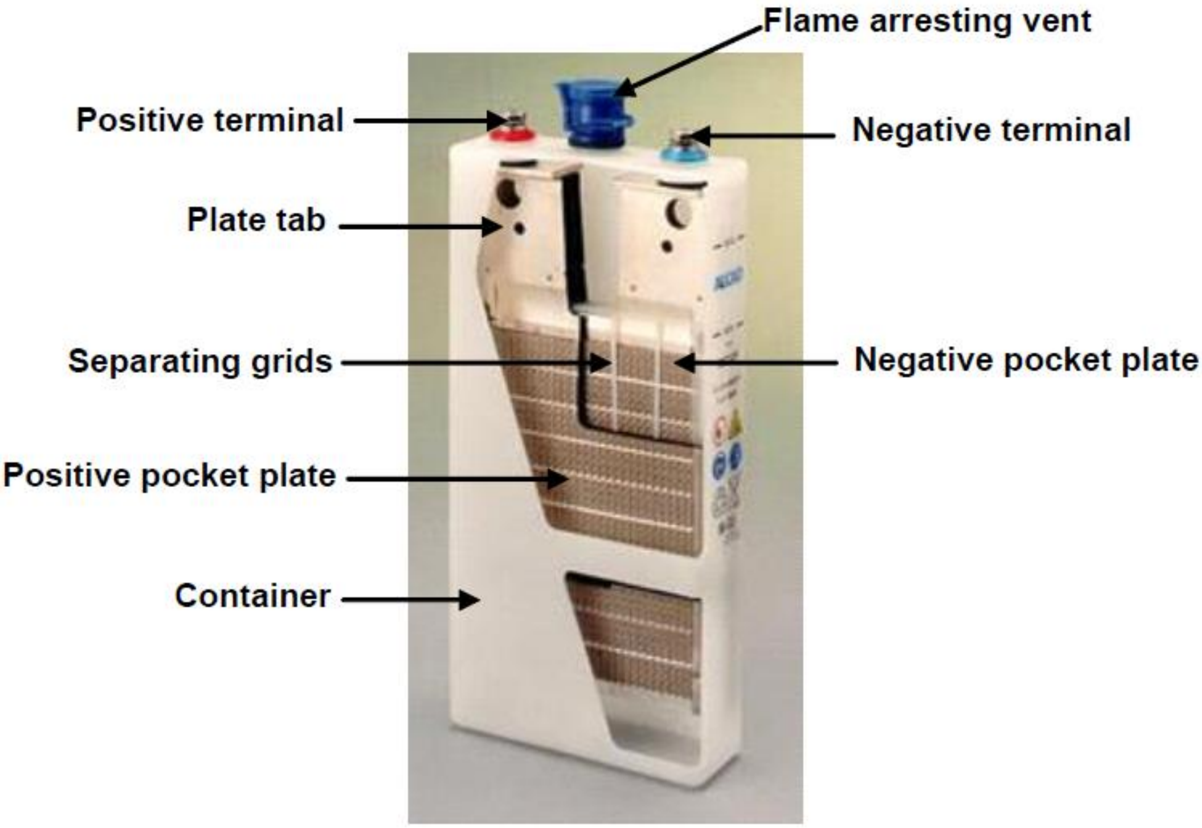


Figure 2: Exploded View of a Nicad Cell

2. Supporting clauses

2.1 Scope

2.1.1 Purpose

This document sets out the requirements, instructions and / or procedures when performing battery commissioning on vented, flooded lead acid (VFLA) –, nickel cadmium (NiCad) – and valve regulated lead acid (VRLA) batteries.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions and to contractors employed by Eskom to perform battery maintenance.

2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] 240-44175132: Eskom Personal Protective Equipment (PPE);

[2] 240-137465740: Standby Battery Storage and Commissioning in Eskom;

[3] 240-51999453: Standard Specification for Valve-regulated Lead-acid Cells;

[4] 240-56360034: Stationary Vented Lead Acid Batteries Standard;

[5] 240-56360086: Stationary Vented Nickel Cadmium Batteries Standard;

[6] 240-62196227: Life-saving rules;

[7] 240-70413856: Authorization procedure for Operating Regulations for High Voltage systems;

[8] 240-87264294: Ohmic Testing of Battery Connections;

[9] 240-89797258: The Safe Handling, Transportation and Disposal of Cells Batteries and Electrolyte;

[10] 36-681: Generation Plant Safety Regulations;

[11] DPC_34-227: Pre-task planning and feedback process;

[12] DPC_34-380: Identifying, Analyzing, Documenting and Observing Tasks According to Criticality.

2.2.2 Informative

[13] OHSAct: Occupation Health and Safety Act 85 of 1993 and Regulations;

[14] ISO 9001, Quality Management Systems;

[15] EPC_32-727, Rev 0, Safety, Health, Environment and Quality (SHEQ) Policy;

2.3 Definitions

2.3.1 General

Definition	Description
Battery Impedance	It is a combination of internal resistance and reactance where internal resistance + reactance, or (L+C), equals impedance when using an AC stimulus. The internal resistance of a battery is made up of two components: electrical or ohmic resistance and ionic resistance.
Cadmium readings	The cadmium readings indicate the plate potential relative to the cell electrolyte which indicates if the cell plates have been properly formed during commissioning. A cadmium rod (stick) is used as reference electrode. When the cadmium electrode is held suspended in the electrolyte and connected to the negative jack of the voltmeter with the positive jack connected through a suitable lead which is pushed against of the positive terminal of the cell, the resultant reading is known as the positive cadmium reading. The negative cadmium reading is obtained by pushing the voltmeter lead from the positive jack to the negative terminal of the cell.
Link Impedance	It is the intercell connection resistance measure across cell posts to enable the detection of any possible loose intercell connections

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
AC	Alternating current
BC	Battery commissioning
BI	Battery Installation

Abbreviation	Description
DC	Direct current
LEDs	Light emitting diodes
MAX	Line on cell indicating the maximum electrolyte level of the cell
MCB	Miniature circuit breaker
MIN	Line on cell indicating the minimum electrolyte level of the cell
NCR	Non-conformance report
OEM	Original Equipment Manufacturer
PPE	Personal protective equipment
SC	Study Committee
SG	Specific gravity
TSS	Technical Specialist Section
UPS	Uninterruptible Power Supply

2.5 Roles and responsibilities

a) The designated person or his/her delegate shall ensure that this task manual is implemented and adhered to.

b) The authorized/responsible person is responsible for the safe execution of all work and activities as set out in this task manual.

c) Only people authorized for activities in this task manual shall perform these duties.

d) The responsible DC person shall keep originals or copies of all commissioning documents.

2.6 Process for monitoring

The DC & Auxiliary Supplies SC shall ensure that this document is updated as and when required.

2.7 Related/supporting documents

Not applicable.

3. Requirements

3.1 General

a) Never use the same maintenance equipment on lead acid and nickel cadmium batteries. Keep the equipment separate and labelled accordingly.

b) Do not store anything other than the maintenance and safety equipment in the battery room.

c) Ensure that in the case of battery operated test instruments; the “battery low” indication is not displayed, which means that the battery should be replaced before taking any measurement.

3.2 Safety precautions

a) The prescribed personal protective clothing as indicated in 240-44175132, Eskom Personal Protective Equipment (PPE), shall be worn when commissioning batteries.

b) The use of naked lights, naked flames, cigarettes, welding equipment and any other equipment capable of generating sparks is prohibited within the confines of the battery room or in close proximity of a battery enclosure.

c) Final connection shall be made at the rectifier and not at the battery to avoid an explosion risk in the battery room due to sparks.

d) Use only well insulated tools when working on a battery.

e) Do not place anything whatsoever on top of the battery.

f) Avoid bodily contact with the battery terminals, cell connectors and busbars.

g) Before taking voltage measurements, ensure that the voltage range selected on the digital multimeter provides adequate resolution and ensure that the selector switch is selected to voltage measurement and not current measurement.

h) Never use the same topping-up equipment or hydrometer on lead acid batteries as on nickel cadmium batteries. Keep the equipment clean, separate and labelled accordingly.

i) Care shall be taken with the disposal of electrolyte, particularly alkaline electrolyte. The requirements of local authorities shall be obtained and adhered to. All disposals of electrolyte and redundant batteries must be done according to 240-89797258, The Safe Handling, Transportation and Disposal of Cells, Batteries and Electrolyte.

j) Adequate ventilation of the battery room shall be available at all times, particularly during initial charging.

k) All measuring instruments shall be calibrated at least once a year.

l) Water shall always be available.

m) The emergency shower, where installed, shall be operational.

3.3 First Aid

a) The electrolyte is harmful to the skin and eyes. In the event of contact with skin or eyes, wash immediately with plenty of water. If eyes are affected, flush with water, and obtain immediate medical attention.

b) Containers with first aid water shall be changed regularly and clearly labelled.

3.4 Task Risk Assessment

a) Carry out a task risk assessment in accordance with the relevant prescribed document.

b) Ensure that all the members of the team take part when the risk assessment is carried out.

c) Ensure that the correct equipment (insulated tools and torque wrench, test – and measurement equipment and personal protective equipment) for the task at hand is used and that it is fit for purpose.

d) Ensure that equipment is in a good state of repair and proper working order.

e) Use equipment only for the operations and conditions for which it is appropriate.

f) Only calibrated meters and test equipment shall be used and ensure that the certificates are valid.

g) Ensure that the Life-Saving rules are adhered to when performing all tasks in this document.

3.5 Personal Protective, Maintenance and First Aid Equipment

a) All personal protective equipment shall be in accordance with 240-44175132: Eskom Personal Protective Equipment (PPE). The following PPE shall be available:

1) Acid / Alkali resistant protective face shield;

2) Goggles;

3) Acid / Alkali resistant apron;

4) Acid / Alkali resistant gloves;

5) Safety Shoes; and

6) An approved Overall.

b) The following commissioning equipment shall be available:

1) Plastic Jug

2) Plastic funnel

3) Plastic top-up bottle

4) Hydrometer

5) Thermometer

6) Voltmeter

7) Impedance meter

8) Ammeter

9) Discharge capacity tester

10) Insulated torque wrench

11) Paper towels

12) Deionised water in a clearly labelled polycan

13) First aid water in clearly labelled polycan

14) Mop and bucket

c) First aid equipment includes a sealed eyewash bottle with a sterile saline solution.

Figure 3 shows a photo of the different PPE, maintenance and first aid equipment required to perform battery commissioning.

Figure 3: Battery personal protective – and maintenance equipment

3.6 Battery Installation tasks

3.6.1 General

Before the erection of battery stands and batteries, the battery room shall be checked for compliance with the order (Scope of works) and Battery room standard specifications as far as possible. A Battery room acceptance checklist shall be completed (see Annex B).

Before installing the battery, the battery cubicle or battery stands and cells shall be checked for any damage, compliance with the order (Scope of works) and specification. A Battery stand acceptance checklist and a Battery acceptance checklist shall be completed (see Annex C and D).

Increased ventilation to be provided during installation and commissioning.

3.6.2 BI Task 1: Torqueing connections

3.6.2.1 Tools and Equipment

a) Fully insulated torque wrench

b) Open-end wrench

c) Neutralising agent

d) Approved protective coating material

3.6.2.2 Special Tools

Not applicable

3.6.2.3 Activities

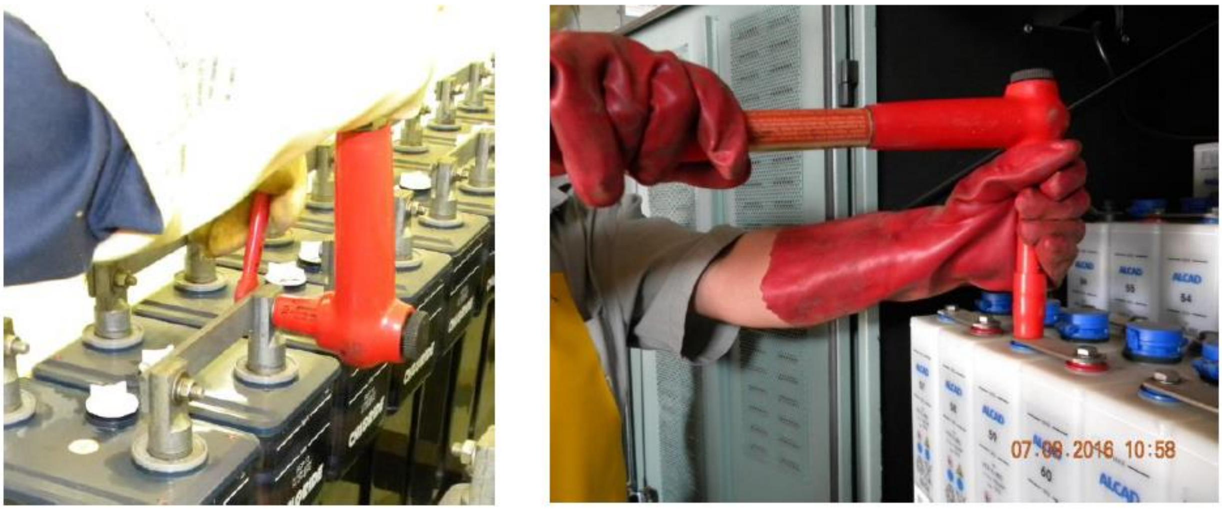
a) Fit inter cell and row connectors as per drawings and hand tighten bolts

b) Tightening of bolts or nuts to be done to the prescribed torque values in the relevant manufacturer datasheets.

c) In the case of bolt-nut connections, two insulated wrenches in counter torque (indicated in the left hand side photo in Figure 4) should be used. Use an open-end wrench on the bolt head, and a torque wrench on the nut.

d) In the case of bolt only connections, only the torque wrench is required as indicated in the right hand side photo of Figure 4.

e) The tightening action should be slow, smooth and not applied in a jerking fashion. Ensure that the cell does not move while tightening the connections.



Vented Flooded Lead Acid cell

Vented Nickel Cadmium cell

Figure 4: Torqueing the connections

f) Be careful not to short circuit posts and connectors of adjacent cells with the torque wrench and open-ended wrench while tightening.

g) Ensure that the protective coating as specified by the specific manufacturer is still intact, after the connections have been torqued, and touch up where necessary.

h) Replace cell covers where applicable.

3.7 Battery Commissioning tasks

3.7.1 General

All measurement equipment shall have a valid calibration status traceable to National Standards, which can be produced on request at any stage during or after the measurement.

A full battery commissioning checklist shall be completed for commissioning the battery (see Annex A).

3.7.2 BC Task 1: Voltage measurement

3.7.2.1 Tools and Equipment

Calibrated Multimeter as indicated in Figure 4.

Figure 5: Calibrated multimeter

3.7.2.2 Special Tools

Not applicable.

3.7.2.3 Activities

a) Before taking voltage measurements, ensure that the correct voltage function and range is selected on the multimeter.

Note: Performing a cell voltage measurement whilst the multimeter is setup for measuring currents will cause a short circuit and can lead to the flow of hundreds of amperes which may lead to equipment damage and personal injury.

b) Measure and record total battery bank voltage at battery positive and negative end posts (i.e. on the first and the last cells of the battery bank) to one decimal point on the battery log sheet.

c) Measure and record the cell voltages on the inter cell connectors / links (this will then also show if there are any loose connections on the volt readings) and record to two decimal places on the battery log sheet.

3.7.3 BC Task 2: Current measurement

3.7.3.1 Tools and Equipment

a) Clamp meter

Figure 6: Calibrated clamp meter

b) Calibrated Multimeter (if the clamp meter does not have an integrated display to read the measurement directly – as the example indicated in Figure 6)

Figure 7: Calibrated multi meter & clamp meter

3.7.3.2 Special Tools

Not applicable.

3.7.3.3 Activities

a) Select the current to be measured to dc.

b) Open the jaws by pressing the tool's trigger.

c) Enclose a single conductor inside the jaws. Make certain the jaws are completely closed before taking readings.

d) View the reading in the display.

e) To measure ac/dc current with a voltage output clamp, turn the dial of the multimeter to mVac for ac current, or to mVdc for dc current.

f) Plug the black test lead into the COM jack.

g) For plug-in clamp accessories that produce a voltage output, plug the red test lead into the V jack. These clamps are designed to deliver 1 mV, 10 mV or 100 mV to the DMM for every 1 A of measured current.

h) Measure and record battery float charge current at the negative pole terminal with the pointer (current direction flow indicator on clamp-on meter) facing away from the battery in milliamps on the battery log sheet.

3.7.4 BC Task 3: Specific Gravity measurement

3.7.4.1 General

a) The specific gravity of a liquid is defined as the weight of a given volume of the liquid divided by the weight of the same volume of pure water at 4 ºC [39 degrees Fahrenheit (ºF)]. The third decimal place is called a "point" and is used in this way: an increase of 5 "points" on 1,315 means an increase from 1,315 to 1,320.

b) The specific gravity is directly proportional to the state of charge or the available capacity of the battery.

c) A suction hydrometer, as shown in Figure 6, is used in stationary vented flooded lead acid battery installations such as those in Eskom's battery rooms. Figure 7 shows a picture of an analogue hydrometer and the float markings. The increments are 5 points.

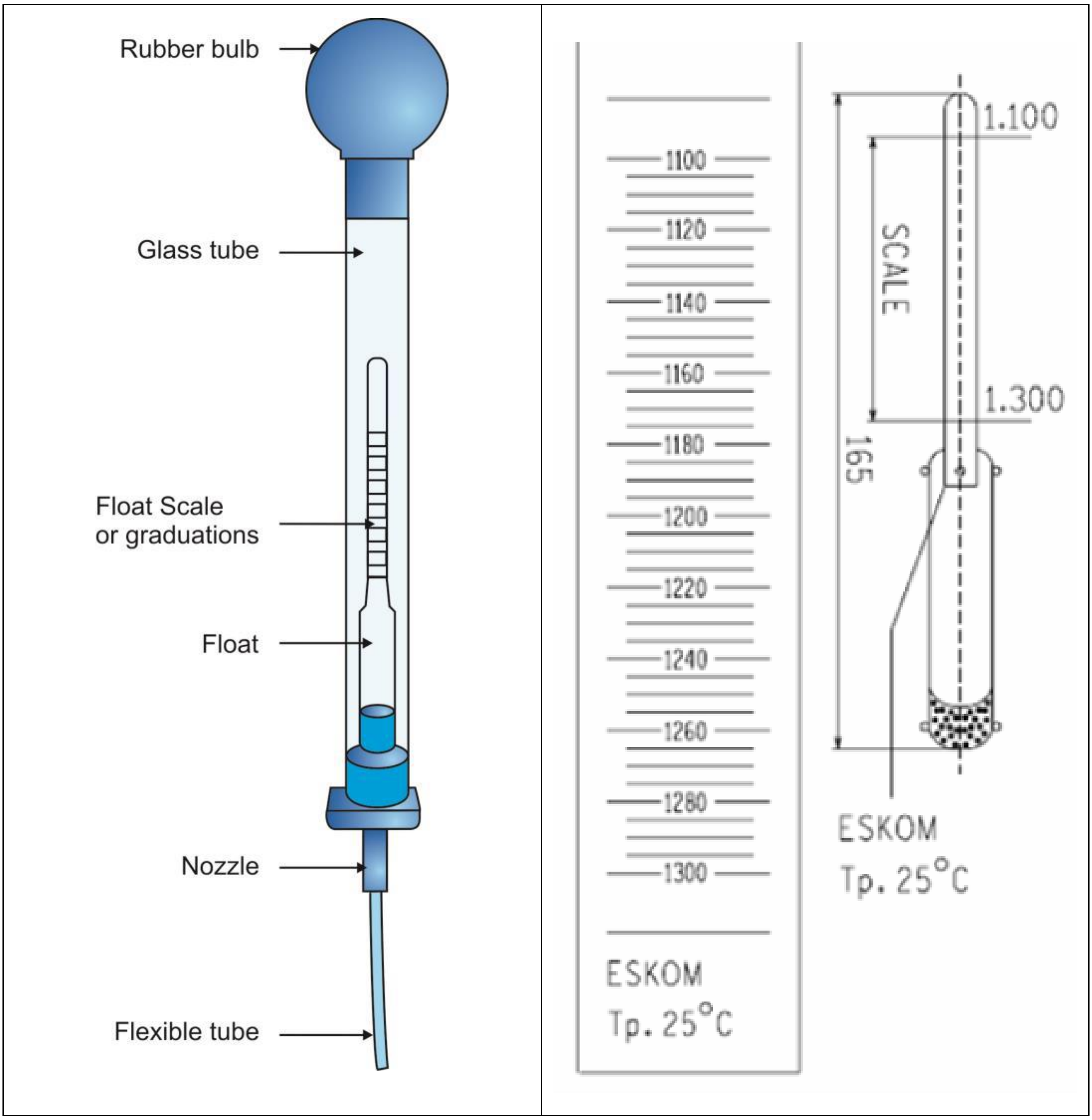


Figure 8: Analogue Hydrometer

3.7.4.2 Tools and Equipment

Approved analogue hydrometer (see 240-51999453)

3.7.4.3 Special Tools

Digital Hydrometer

3.7.4.4 Activities - Analogue Hydrometer

a) Before using the hydrometer, check the following:

1) Check the hydrometer you are using is for the battery type you are maintaining;
2) The rubber parts are not cracked or perished;
3) The syringe (glass tube) is not cracked or damaged;
4) The float is not cracked or damaged;
5) The internal weight is not cracked or damaged.
6) The hydrometer must be free from contamination and dust before readings are taken. Clean with distilled water before and after use.
7) If any one of the above is not correct, change the hydrometer and check again.

b) Readings must be taken with the electrolyte level above the minimum mark. The hydrometer used must be of the approved type and calibrated.

c) Remove the battery vent plug and place in a clean jug or upside-down on the cell lid.

d) In the case of recombination units, the supplied holder should be used to ensure the unit stays upright or use the special purpose opening in the cell lid.

e) In Hoppecke cells provision has been made for SG readings through an additional access plug next to the negative post thus the recombination or vent plugs can stay on the cells during the measurement of the SG (see Figure 8 below)

Figure 9: Additional access plug on Hoppecke cells

f) A sample of the electrolyte is extracted from the cell into the glass float chamber by squeezing and gently releasing the bulb. The hydrometer must be held vertical with the suction tube as far into the electrolyte as possible.

g) Do not hold the bulb of the hydrometer when taking a reading as this may lead to an incorrect specific gravity reading.

h) Hold the hydrometer by the glass tube and make sure that the float does not touch the sides of the glass tube (float chamber).

i) Read the specific gravity as indicated by the weighted float in the hydrometer.

j) The hydrometer must not be removed from the electrolyte when taking a reading.

k) Record the specific gravity (SG) with a hydrometer capable of a resolution of 0,005, e.g. 1,215. The actual hydrometer reading must be recorded without making temperature correction.

l) The bottom of the meniscus formed by the acid gives the true specific gravity readings. Read the centre of the meniscus, i.e. bottom for liquids (see Figure 8).

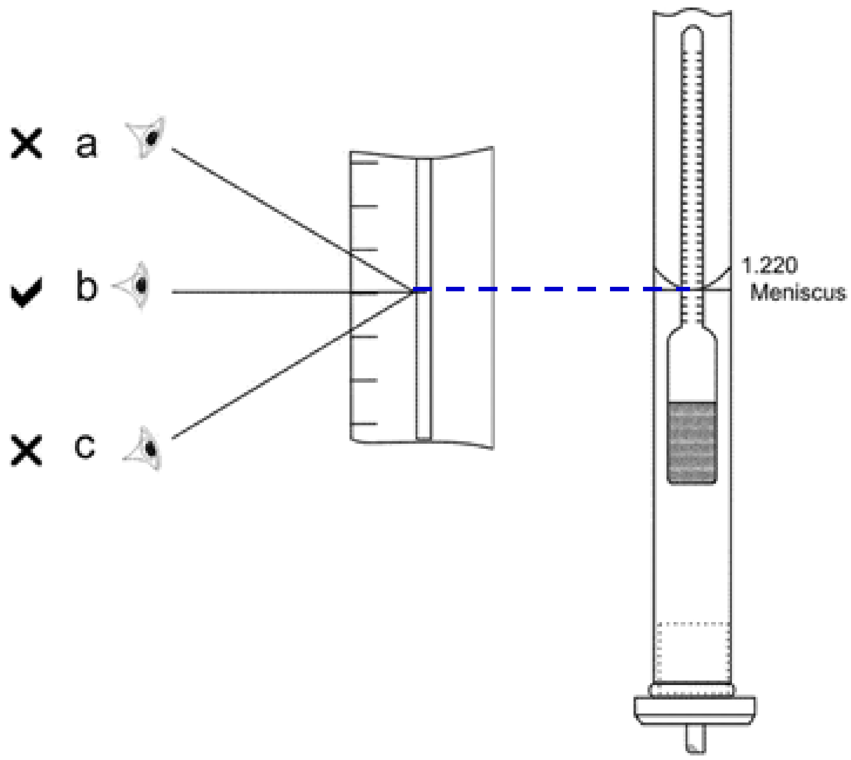


Figure 10: Typical SG meniscus reading

m) Record the measurement on the commissioning log sheet.

n) When the reading has been taken, depress the hydrometer rubber bulb to return the complete electrolyte sample to the same cell from which it was extracted (to prevent inter-cell contamination).

o) Do not spill any electrolyte - if spilled, clean up with a paper towel and dispose in suitable acid proof bin.

p) Replace the vent cap.

q) Repeat on the other cells of the battery bank.

Note: The low reading inscriptions of the hydrometer are at the top of the stem and the high reading inscriptions at the bottom. This is the reverse of an ordinary thermometer scale.

r) Rinse the hydrometer with distilled water, after all the cell readings have taken.

s) Store the hydrometer in the correct place / container.

3.7.4.5 Activities - Analogue Hydrometer

a) Figure 10 shows a picture of a typical digital hydrometer used in Eskom.

Figure 11: Digital Hydrometer

b) Remove the battery vent plug and place in a clean jug or upside-down on the cell lid.

c) In the case of recombination units, the supplied holder should be used to ensure the unit stays upright or use the special purpose opening in the cell lid.

d) Ensure that the instrument is properly setup for the task at hand, following the instructions as indicated in the instruments user manual.

e) Extract a sample of the electrolyte from the cell by using built-in syringe pump as indicated in the instructions as indicated in the instruments user manual.

f) Record the SG reading on the battery log sheet as indicated on the instrument’s display.

g) Return the electrolyte sample to the cell and repeat the process on the remainder of the cells in the battery bank, if part of the activity.

h) Rinse the hydrometer with distilled water, after all the cell readings have taken.

i) Store the hydrometer in the correct place / container.

3.7.5 BC Task 4: Temperature measurement

3.7.5.1 General

a) An alcohol glass thermometer is used to measure the electrolyte temperature of the cells. Mercury type thermometers shall not be used because the mercury in it may cause a short circuit if it breaks whilst inserted in the electrolyte.

b) Monitoring of battery cell temperature during commission initial charging is an critical function to prevent any possible thermal runaway which would damage the cells.

3.7.5.2 Tools and Equipment

Approved alcohol (blue / red liquid) thermometer (see 240-51999453) as indicated in Figure 11 below.

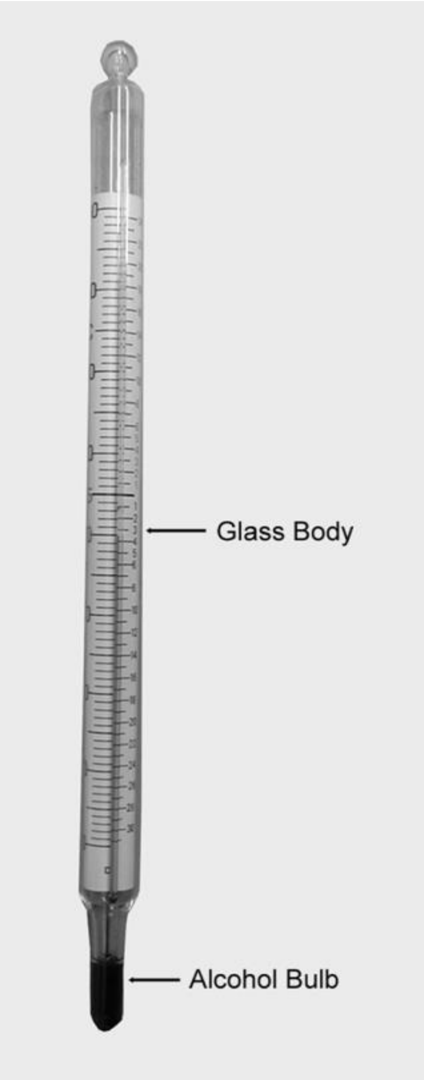


Figure 12: Alcohol thermometer

3.7.5.3 Activities - Analogue thermometer

a) Before using the thermometer check for the following:

1) This is a fragile instrument and must be handled with care. Check that it is not cracked or damaged.

2) Ensure that the alcohol volume is continuous and not fragmented

3) If thermometer is damaged, replace the thermometer with a new one.

b) Remove the battery vent plug and place in a clean jug or upside-down on the cell lid. In the case of recombination units, the supplied holder should be used to ensure the unit stays upright.

c) On Hoppecke cells, use the access plug on the cell as indicated in Figure 8.

d) Carefully place the thermometer into the electrolyte with alcohol bulb first ensuring that it is firm and does not slide into the cell.

e) Allow time for the alcohol in the thermometer to stabilize with the bulb still in the electrolyte.

f) Keep the thermometer vertical and record the temperature reading on the applicable space provided on the logsheet.

g) Remove the thermometer taking care not to spill any electrolyte.

h) Replace the vent plug.

i) Clean any spillage of electrolyte with a dry paper towel and dispose in a suitable acid-proof bin.

j) Clean the thermometer and place in a safe place.

3.7.5.4 Activities - Infrared, non-contact thermometer

a) Infrared thermometers measure the surface temperature of an object. The unit's optics sense emitted (E), reflected (R), and transmitted (T) energy, which is collected and focused onto a detector as illustrated in Figure 11. The unit's electronics translate the information into a temperature reading which is displayed on the unit. The laser/s is used for aiming purposes only.

Figure 13: Infrared thermometer

b) Perform all cell temperature measurements as prescribed in the instrument's user manual.

3.7.6 BC Task 5: Cell ohmic testing

3.7.6.1 General

a) The cell / battery impedance, Z, is a complex value that depends on the frequency (f). The inductance can be neglected because of its small magnitude. The capacitance on the other hand is very large on account of the large surface area of the electrodes. Typical instruments used perform ohmic based measurements are impedance testers, conductance testers and internal resistance testers. The manufacturers of all these different testers (see Figure 12 for examples of ohmic testers) claim that their testers can indicate a cell's state-of-health by measuring the change in impedance values of each cell. The cell impedance readings after commissioning are therefore taken and recorded as a baseline value for future operational measurement comparisons.

Fluke BT521 Advanced Battery Analyzer

Midtronics Advantage

Figure 14: Battery ohmic testers

b) These testers are also be used to measure the integrity of cell-link connections after installation and commissioning.

3.7.6.2 Special Tools

a) Midtronics Advantage conductance tester.

b) Fluke BT521 Advanced Battery Analyzer.

3.7.6.3 Activities

a) The ohmic test is performed online as the final check during commission of the cells. This is done with the battery bank connected and on float charge.

b) Perform all cell and cell-link measurements as prescribed in the instrument's user manual.

c) Download the data from the tester into the database and put copies with the commissioning sheets.

3.7.7 BC Task 6: Battery Capacity Testing

3.7.7.1 General

Suitable values of constant discharge current, discharge duration and final cell voltage shall be decided on before the test in accordance with the relevant standards or the battery manufacturer's specifications. The discharge current shall be held constant within 1% throughout the duration of the test. The constant current shall be maintained by using a discharge test set. The battery bank voltage shall be captured via an automated discharge voltage logging that is date and time stamped.

3.7.7.2 Special Tools

Discharge machine – see Figure 15.

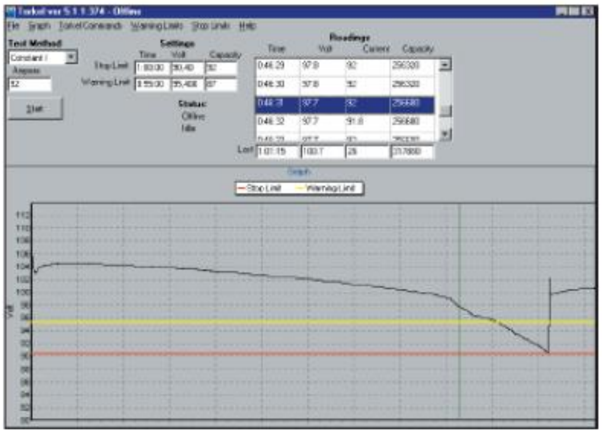


Figure 15: Example of a discharge test machine and discharge test report

3.7.7.3 Activities

a) Switch the battery charger off and disconnect the battery from the battery charger

b) Take a full set of open circuit battery readings

c) Set up discharge unit in well ventilated area.

d) The discharge test can be conducted over the ten or five hour period. The manufacturer provides these capacities as well as final voltages (end-of-discharge voltages). Refer to tables in technical manuals.

e) Note: If the battery application requires a discharge at any other rate, the battery should be discharged at that rate, in accordance with the manufacturer’s data.

f) Discharge shall commence at earliest after 1 hour and before 24 hours after completion of the initial charge.

g) Start the discharge test set, check the discharge current and log the time. The discharge current shall not deviate more than ± 1% from the set value over the whole discharge period. Short term deviations of within ± 5% of the set value shall be tolerated.

h) Battery bank voltage, cell voltages, current and pilot cell temperature readings shall be taken at least at 25%, 50% and 80% of the calculated discharge time, and thereafter at intervals that allow the reaching of the final voltage to be detected. A recommendation is that readings shall be taken at 30 minutes intervals during the last hour. Readings are to be recorded on the correct battery technology commissioning sheets with a sheet/set of readings that is selected from Annex H, Annex I or Annex J for each time interval.

i) The discharge test shall be complete when the predetermined time of discharge has elapsed or when all cell voltages fell below the final end-of-discharge voltage before the discharge time has lapsed.

j) After the completion of the discharge test, switch the discharge test set off and disconnect it from the battery. A Discharge Summary Sheet (Annex F) must be completed after completion of the test.

k) For flooded lead acid cells take a full set of SG and pilot cell temperature readings.

l) Disconnect battery bank from the discharge unit.

3.7.8 BC Task 7: Battery Cadmium readings

3.7.8.1 General

The cadmium reading indicates the plate potential with relation to the electrolyte. When the cadmium electrode is held suspended in the electrolyte and connected to the negative post of the voltmeter with the positive post connected through a suitable lead and prod to the positive terminal of the cell, the resultant reading is known as the positive cadmium reading.

Cadmium reading must be done during charging when the battery is at the end of the initial charge. It can be very helpful in determining possible internal defects during the formation charging and will indicate when the plates are completely charged.

Expected Cadmium readings for First National Battery (FNB) in a fully charged condition under normal temperature (25°C) are shown below. The cell voltage is given by the algebraic difference of the electrode potentials.

Positive Cadmium 2.40V

Negative Cadmium - 0.15V

$$V_{cell} = V_{pos\,Cd} - V_{neg\,Cd}$$

$$= 2{,}4 - (-0{,}15)$$

$$= 2{,}55 \text{ V}$$

It will be noted that the negative cadmium reading has gone into reverse or minus direction, which is normal.

Positive cadmium readings taken under fully charged conditions at the finish rate will always be uniform in a normal battery. If the positive cadmium readings are more than 0.05 volts lower than the surrounding cells, it must be inspected for possible defects.

3.7.8.2 Tools and Equipment

a) Multimeter

b) Cadmium stick

3.7.8.3 Activities

a) Cadmium electrodes can be stored in sulphuric acid with an SG of ±1,100 or dry. For maximum accuracy, it is recommended that the electrode be conditioned (soaked) in this acid for at least 30 minutes before use. The sulphuric acid corrodes the surface of the electrode, and an equilibrium state is eventually reached.

b) Cadmium readings should only be taken when a cell is on charge or on discharge. Open circuit Cadmium readings are meaningless.

c) For the end-of-charge, the ideal test current flowing will be 7%Crated (total rated capacity, normally C10) e.g. a 50Ah rated battery has a current of 3,5A flowing and a 100Ah battery should have a current of 7A flowing.

d) To use the electrode, the male jack plug is inserted into the neutral socket of the voltmeter (multimeter). The electrode is placed in the electrolyte. Ensuring that the Cadmium stick does not make electrical contact with any lead in the cell, and allowed to attain the temperature of the electrolyte, the positive plate potential can now be measured by touching the positive terminal (post) with the positive probe (lead) of the voltmeter. Similarly, the negative plate potential is measured by touching the negative terminal (post) with the positive probe (lead) of the voltmeter.

Figure 16: Cadmium stick and connected to Voltmeter

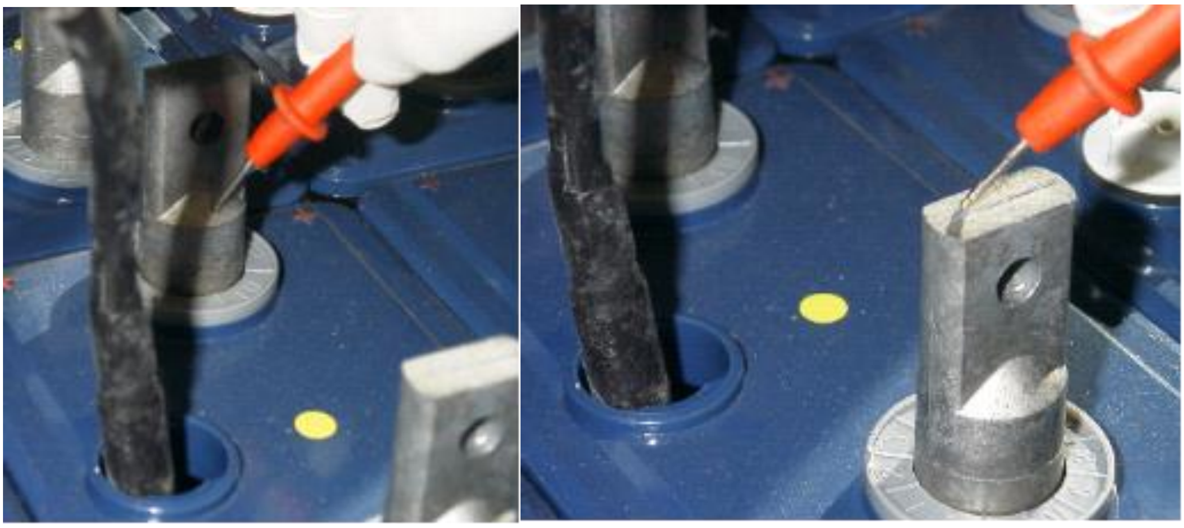


Figure 17: Taking positive and negative Cadmium reading

e) Temperature variations do affect negative cadmium readings, which results in lower cadmium readings at hotter temperatures and higher cadmium readings at colder temperatures.

f) Any negative cadmium readings that go to plus side of zero, at any temperature, should be looked upon with suspicion, as such battery will usually have poor charge retaining ability.

3.8 Battery Installation and Commissioning execution

3.8.1 Battery Installation

3.8.1.1 Battery Cubicles

a) Position cubicle correctly in accordance with the applicable drawings.

b) Ensure that cubicles are perfectly level over the length and width.

c) Cubicles must then be securely mounted to wall or trench

d) Earthing of the battery cubicle to station earth must be done via the earthing stud provided on the cubicle

3.8.1.2 Battery Stands

a) Assemble and position stands correctly in accordance with the applicable drawings.

b) Plug holes in stands with plugs provided, but where screw holes remain these shall be plugged with putty.

c) Touch up paintwork where necessary.

d) Ensure that stands are perfectly level over the length and width.

3.8.2 Unpacking of the batteries

a) Check for cracked jars or damaged lids or damaged terminals.

b) Check that cell polarities are correct and clearly marked.

c) Check cell plates are still intact.

d) Check that all accessories are correctly supplied, i.e. nuts, bolts spring washers, inter cell connectors, cell numbers.

e) Clean off any dust with a paper towel. (Scouring powders or solvents, e.g. Handy Andy, shall not be used for cleaning the jars or lids as scratching or damage to the surface of the container may result)

f) Ensure that the batch manufacturing dates on the cells correspond.

3.8.3 Packing and linking the cells

a) Pack the cells such that the edges of the plates are clearly visible.

b) Apply a thin layer of petroleum jelly or no-oxide grease to inter cell connectors and terminals. Connector and terminal coating shall be according to the manufacturer’s recommendations.

c) Fit inter cell connectors and hand-tighten nuts and bolts.

d) Line cells up straight and neatly ensuring that the specified distance between cells is maintained. Ensure that the correct polarities are maintained.

e) Tighten to the manufacturer’s prescribed torque settings using an insulated torque wrench.

f) Fit inter-row connectors and the battery terminating set.

g) Battery connectors shall be colour-coded red for positive, blue for negative and white for inter-row connectors and the monitoring tap. Connectors can be solid copper bars or flexible cable. Where flexible connectors are used, the crimped lugs must be sealed with adhesive heat shrink. Colour code flexible cables on the ends with coloured heat shrink. Note: The cable size should be properly sized for the battery load.

h) Number the cells with number one starting at the positive end. It is important to ensure that the numbers are visible and do not hide the cell maximum and minimum lines.

i) Mount the battery identification label. The label must be clearly visible and mounted above the battery bank, on the wall, or on the battery stand.

j) The battery is now ready to be filled.

k) Complete the Battery stands acceptance checklist and the Battery acceptance checklist (see Annex C and D).

3.8.4 Battery Commissioning

3.8.4.1 Filling the cells

a) During this phase of the commissioning process, it is important that the appropriate personal protective equipment is used. Adherence to the Eskom standard 240-89797258, The Safe Handling, Transportation and Disposal of Cells, Batteries and Electrolyte shall apply.

b) Check and log the SG of the electrolyte in each container before it is used to fill the cells. The SG value shall comply with the manufacturer's specification and not vary by more than ± 5 points between cans. Shake container or stir electrolyte to mix the acid before taking the SG readings. When checking the SG's, ensure that temperature correction is taken into consideration.

c) Clean all filling equipment with distilled water and ensure that it is operational. Ensure that all couplings are secure and hoses are in good working order (acid pump).

d) Fill the cells with electrolyte to the maximum mark. Be careful not to overfill cells above the maximum mark. If cells were accidentally overfilled the excess electrolyte should be removed using the hydrometer. Log the date, time, electrolyte temperature and ambient temperature after filling.

e) Never overfill the cells to compensate for trapped air bubbles. Each cell behaves differently and overfilling will affect the SG level of the electrolyte.

3.8.4.2 Resting the cells

Leave the filled cells standing for a minimum of 4 hours and a maximum of 24 hours.

3.8.4.3 Initial charging

a) Before commencing with the initial charge, ensure that the cell temperatures are as near to ambient temperature as possible. Do not commence initial charge until the electrolyte temperature is below 40°C.

b) If the ambient temperature is a limiting factor for initial charging, reduce the charging current and try to perform the charging process during cooler periods of the day (early mornings or evenings).

c) Before commencing initial charging, check electrolyte level and top up to the maximum mark with electrolyte if necessary. Acid can only be added before commencing with initial charge, thereafter use only approved de-ionised water.

d) Complete initial charge log sheets. Select the correct battery commissioning sheet and complete a sheet/ set of sheets at each time interval. Select fixed time intervals for readings of cell voltages, current, SG's and electrolyte temperatures of pilot cells, so that changes in cell readings have a reference from which adjustments can be made.

e) Take a full set of open circuit readings and note abnormalities. The electrolyte shall be on the maximum mark when taking readings.

f) Confirm the correct polarity of the cells by checking the open circuit voltages. Contact the project leader if the polarity is incorrect to the terminal identification on the cell.

g) Select pilot (reference) cells. These will be the cells with abnormally high or low SG and voltage readings. Ensure that there is at least one reference cell at the end of the bank (i.e. more subject to ambient) and one reference cell in the middle of the bank (warmer than outside cells). It is advisable to use every 6th cell.

h) It is recommended that 4 sets of pilot cell readings be taken every 24 hours. Recommended times for taking readings are 08:00, 12:00, 16:00 and 23:00.

i) Set the charging system to “initial charge” mode, a constant current charge, switch ON and log time.

j) Start charging at 7% of the rated capacity (C10). Adjust the initial charging current between 3,5% and 15% of the ampere-hour rating of battery at the 10h rate. Ensure that the temperatures of the electrolyte of the pilot cells do not exceed the OEM maximum value. Whenever the electrolyte temperature does exceed the maximum specified value, reduce the current setting or stop charging until the electrolyte temperature has dropped.

k) Take a full set of battery cell readings. Thereafter take a set of pilot cell readings at the recommended (mentioned above) or selected times for the remainder of the initial charge.

l) Continue taking readings and charging as recommended above until the OEM recommended minimum charge has been accepted by the battery and the cell voltages and SG’s have stabilised, at approximately 2,6V to 2,7V per cell between three consecutive hourly readings. The initial charge voltage must be set higher than 2.8V per cell to ensure constant current charge is maintained and the cell voltages will develop as high as the chemical reaction will allow.

m) On each set of readings document the calculation of the Amp-hours accumulated at that reading interval. This will serve as reference to the minimum period of charge before consecutive readings will be evaluated to monitor if voltages and SG’s have stabilized and the initial charge process can be stopped.

n) If the charging current is reduced in order to control the temperature the initial charge time and number of readings will increase until the battery is deemed fully charged.

o) If neither the voltage nor the SG’s stabilise after continuous charging to a maximum of 5 x C10, the non-compliant cells are not acceptable and they shall be replaced.

p) Take a full set of readings including cadmium readings at a charging current of 7% C10 (refer to section cadmium sticks). Results are to be noted on Cadmium Test Sheet. Select the correct system voltage sheet/set of sheets (for 220V) from Annex F.

q) For flooded lead acid cells take cadmium readings of all cells. Cadmium Tests should be done at 7%IC10 just before the initial charge process is terminated. This will give evidence of the correct formation of the positive and negative plates as the voltage will be influenced by the final SG and state of charge of each cell.

r) The charger shall then be set to the float mode at the correct float voltage for a minimum of 12 h to allow the battery to stabilise (e.g. temperature, voltage, etc.).

Note: A **full set of readings** will include the following:

Note: 1) All cell voltages

Note: 2) All cell SG’s

Note: 3) Pilot cell electrolyte temperatures

Note: 4) Ambient temperature

Note: 5) Battery voltage

Note: 6) Battery current

Note: 7) Amp-hours accumulated

Note: A set of pilot cell readings will include the following:

Note: 1) All cell voltages

Note: 2) Pilot cell SG's

Note: 3) Pilot cell electrolyte temperatures

Note: 4) Ambient temperature

Note: 5) Battery voltage

Note: 6) Battery current

Note: 7) Amp-hours accumulated

3.8.4.4 SG Adjustment Procedure

a) Top the cells up to the "MAX" mark.

b) Boost charge the batteries for a minimum of 2 hours to ensure that the electrolyte is thoroughly mixed.

c) Perform SG adjustments with the cells gassing.

d) Take a full set of SG readings.

e) Verify that the SG values are within the specified ranges. If not, then proceed with SG adjustments.

f) If the SG is high, adjustment is done by removing the calculated volume of electrolyte and replacing it with an equal volume of de-ionised water. Add a small amount of water at a time, with the cells gassing, to help mix the water with the acid. When thoroughly mixed, read the SG.

g) If the SG is too low, remove the calculated volume of electrolyte and replace it with an equal volume of stronger sulphuric acid in small amounts gassing (mixing) as described above.

h) Repeat the process until the specified tolerance (see table) is achieved.

i) When the adjustment has been completed, ensure that the electrolyte levels are on the "MAX" mark and the charger is set to the float mode.

j) The following equation may be used to determine the amount of electrolyte that must be removed and the amount of acid or water to replace it with for cells with electrolyte level on "MAX":

$$V_2 = \frac{S_1 V_1 (C_3 - C_1)}{S_2 (C_2 - C_3) - S_1 (C_1 - C_3)} \quad \text{..................1)}$$

where:

S1 = Specific gravity of acid to be adjusted

V1 = Volume of acid to be adjusted

C1 = % H_2SO_4 of acid to be adjusted

S2 = Specific gravity of added acid or water

V2 = Volume of electrolyte removed and volume of added acid or water

C2 = % H_2SO_4 of added acid or water

C3 = % H_2SO_4 of required acid

3.8.4.5 Temperature correction of SG

a) Rule 1: For every 10°C above 25°C, add 7 points (0.007) to the reading.

b) Rule 2: For every 10°C below 25°C, subtract 7 points (0.007) to the reading.

$$SG_2 = SG_1 + \frac{0.007(T_1 - 25)}{10}$$

………………..2)

where:

SG1 = Specific gravity of electrolyte at the actual electrolyte temperature

SG2 = Specific gravity of electrolyte corrected to 25°C

T1 = Actual electrolyte temperature

c) Refer to Annex K for examples of SG adjustment calculations. Annex M shows an SG adjustment table that can be used instead of formula 1).

3.8.4.6 Discharge tests

Conduct a full capacity discharge test as per Item 3.7.7 BC Task 6: Battery Capacity Testing

3.8.4.7 Acceptance

If any cell's voltage falls below the manufacturer's recommended final voltage per cell within the discharge period specified in the purchase contract, the cell will be classified as faulty and shall be replaced. A new battery being repeatedly discharged and charged as specified by the manufacturer, shall supply at least Ca = 0,95 Crt at the first cycle. If this is not reached the bank will be seen as failed and replaced. If the bank achieved more than 0,95 Crt it must achieve Ca = Crt at the second cycle to pass.

3.8.5 Battery commissioning completion final checks

a) Check the voltage settings for the float and equalise modes.

b) Make sure that all cells are clean, dry and apply an approved coating material as per manufacturers.

c) Take a full set of impedance –, conductance – or internal resistance readings for the individual cells and the connecting links. These measurements will provide the following benefits:

d) Documented proof of correct torqueing of cells.

e) Documented proof of no cell damage during transport and commissioning of cells.

f) Baseline ohmic measurement of internal cell plates for future reference.

g) Connect load.

h) Hand over to customer.

i) Until such time as the substation or new installation is handed over it shall be the responsibility of the DC Section to carry out routine maintenance on the batteries and chargers in accordance with the 240-108614750, Rev 1: DC supply equipment maintenance standard.

j) Complete the Battery In/Out Commissioning Sheet (Annex N) and forward a copy to the Plant Management Section to update the assets management database.

k) A final comment is that although several commissioning sheets has been developed and made available in the annexes to provide a standardised data collection format, automated data collected for cell readings which are date and time stamped are preferred. If the specific meter provides for information such as the project & site name, they can be printed and used for the commissioning data as is.

l) Complete all relevant checklist and commissioning sheets as per 240-137465740: Rev 0, STANDBY BATTERY STORAGE AND COMMISSIONING IN ESKOM.

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Thomas Jacobs	Chief Engineer – DC & Auxiliary Supplies
Edison Makwarela	Metering, DC & Security Technologies Manager (Acting) – PTM&C CoE
Richard McCurrach	Senior Manager – PTM&C CoE
Prince Moyo	Power Delivery Engineering GM
Prudence Madiba	Senior Manager Electrical and C&I Engineering

5. Revisions

This document supersedes the following documents fully:

DMN34-1723: Distribution Task Manual – Part 16: Battery Commissioning (Dx);

DMN34-1724: Distribution Task Manual – Part 16: Battery Installation (Dx).

Date	Rev	Compiler	Remarks
July 2019	1	C van Zyl	New document.

6. Development team

Eskom Battery Care group

7. Acknowledgements

Not applicable.

Annex A – DC Equipment Commissioning Cover Sheet

Eskom	BATTERY COMMISSIONING COVER SHEET	Page		
		1	of	6

Project / Works Order / Task Order No.:		**Starting Date:**	
Site Name:			
Drawing No.:			
Battery Function:			
Battery Manufacturer:		**Model:**	
Standards/Specifications:	**240-56360034, Stationary Vented Lead Acid Batteries Standard** **240-56360086, Stationary Vented Nickel Cadmium Batteries Standard** **240-51999453, Standard Specification for Valve-Regulated Lead Acid Cells** **240-56177186, Battery Room Standard**		

Number	Item	Contractor	Eskom
1	Battery Room Acceptance Checklist		
2	Battery Stand / Cubicle Acceptance Checklist		
3	Battery Acceptance Checklist		
4	VLA Battery Initial charge Checklist 1)		
5	Battery Discharge Checklist		
6	Battery Commissioning Sheets 1)		
7	Battery Cadmium Sheets 2)		
8	Battery In/Out Commissioning Sheet		

Notes:

Applicable items to be signed off by contractor and Eskom representative

Checklists 1-5 to be completed where applicable

1) Selected applicable battery technology commissioning sheets, to be used for charge and discharge logging

2) Only applicable to VLA batteries

Done by Contractor	**Signature**	**Date**
Approved by Eskom	**Signature**	**Date**

Annex B – Battery Room Acceptance Checklist

Eskom	BATTERY ROOM ACCEPTANCE CHECKLIST	Page		
		2	of	6

Project / Works Order / Task Order No.:		**Date:**	
Site Name:			
Drawing No.:			
Standard/Specification:	**240-56177186, Battery Room Standard**		

Number	Item	Contractor	Eskom
1	Battery Room construction as per design drawing		
2	Battery room requirements as per divisional specifications		
3	Floor sloping towards chemical resistant gulley		
4	Chemical resistance epoxy floor coating, light grey colour		
5	Door entrance elevated to ensure electrolyte containment		
6	Walls painted with acid resistant primer and white enamel		
7	Running water provided 1)		
8	Taps with sink with acid trap 2)		
9	Deluge shower & eyewash installed and operational 1)		
10	Ventilation will be as per battery room specification 3)		
11	Safety signs provided and positioned as per battery room standard		
12	The luminaires shall be mounted in parallel with the battery stands, but not over the battery stands		
13	Electrical installations in battery rooms issued with a Certificate of Compliance (CoC).		
14	Battery rooms with alarms installed shall comply with battery room standard(1)		
15	Battery maintenance and safety equipment holder or enclosure provided		

Notes:
1) Not a requirement for Eskom Distribution and Eskom Telecommunication
2) Only sink required for Eskom Distribution and Eskom Telecommunication
Can be forced or natural ventilation depending on the design, design to comply with battery room standards

Done by Contractor	**Signature**	**Date**
Approved by Eskom	**Signature**	**Date**

Annex C – Battery Stand and Battery Cubicle Acceptance Checklist

Eskom	BATTERY STAND / CUBICLE ACCEPTANCE CHECKLIST	Page		
		3	of	6

Project / Works Order / Task Order No.:		**Date:**	
Site Name:			
Drawing No.:			
Standards/Specifications:	**240-56360034, Stationary Vented Lead Acid Batteries Standard** **240-56360086, Stationary Vented Nickel Cadmium Batteries Standard** **240-51999453, Standard Specification for Valve-Regulated Lead Acid Cells**		

Number	Item	Contractor	Eskom
1	Battery stand		
1.1	Battery stand complies to standards and as per drawings		
1.2	All battery stand components delivered and correct		
1.2	Battery stand correctly positioned and level		
1.3	Bolt and screw holes plugged		
2	Battery Cubicles		
2.1	Battery cubicle complies to standards and as per drawings		
2.2	Battery cubicle inspected for any damage		
2.3	Battery cubicle installed as per design layout drawings		
2.4	Battery cubicle level and securely mounted		
2.5	Battery cubicle safety signs fitted		

Note: Mark the non-relevant portions just as N/A		
Done by Contractor	**Signature**	**Date**
Approved by Eskom	**Signature**	**Date**

Annex D – Battery Acceptance Checklist

		Page		
Eskom	**BATTERY ACCEPTANCE CHECKLIST**	4	of	6

Project / Works Order / Task Order No.:		**Date:**	
Site Name:		**Battery Order No.**	
Battery Function:			
Battery Manufacturer:		**Model:**	
Standards/Specifications:	**240-56360034, Stationary Vented Lead Acid Batteries Standard** **240-56360086, Stationary Vented Nickel Cadmium Batteries Standard** **240-51999453, Standard Specification for Valve-Regulated Lead Acid Cells**		

Number	Item	Contractor	Eskom
1	Type, make, Ah rating and number of cells correct as per design		
2	No visible damage to cells		
3	All battery components delivered and correct		
4	Cells positioned correctly, lined up straight and neat		
5	Inter-cell, inter-row and battery terminating devices fitted and torqued to the correct settings		
6	Intercell connection and cell impedance measurements taken as per standards after commission done		
7	Approved protective coating applied to intercell connectors, bolts and nuts		
8	Recombination units inserted on the vent plugs of the VLA battery cells		
9	All battery cells cleaned and neat		

Note: Recombination units only applicable to VLA batteries, mark as N/A for other battery types		
Done by Contractor	Signature	Date
Approved by Eskom	Signature	Date

Annex E – VLA Battery Initial charge Checklist

Eskom	**VLA BATTERY INITIAL CHARGE CHECKLIST**	Page		
		5	of	6

Project / Works Order / Task Order No.:		**Date:**	
Site Name:			
Battery Function:			
Battery Manufacturer:		**Model:**	
Standards/Specifications:	**240-56360034, Stationary Vented Lead Acid Batteries Standard**		

Number	Item	Value
1	Average SG of electrolyte in containers	
2	Average temperature of electrolyte in containers	°C
3	Initial charging current (Ideal 7% of C_r Max 15% of C_r)	A
4	Time and date of filling cells	Time Date
5	Time and date of commencing charge	Time Date
6	Time and date of cells starting to gas	Time Date
7	Time and date of when current set at 7% of C_r	Time Date
8	Time and date when voltage & SG stabilised	Time Date
9	SG corrections done (Yes/No)	Yes/No
10	Time and date of Cadmium readings	Time Date
11	Time and date when 12 hour float charge initiated	Time Date
12	Resting period before start of discharge test	Hours

Note: VLA batteries is the only battery technology initial charged by contractors or Eskom, all other battery types are initial charged at the OEM factories

Done by Contractor	**Signature**	**Date**
Approved by Eskom	**Signature**	**Date**

Annex F – Battery Discharge Checklist

Eskom	**BATTERY DISCHARGE CHECKLIST**	Page		
		6	of	6

Project / Works Order / Task Order No.:		**Date:**	
Site Name:			
Battery Function:			
Battery Manufacturer:		**Model:**	
Standards/Specifications:	**240-56360034, Stationary Vented Lead Acid Batteries Standard** **240-56360086, Stationary Vented Nickel Cadmium Batteries Standard** **240-51999453, Standard Specification for Valve-Regulated Lead Acid Cells**		

Number	Item	Value
1	Nominal capacity rating: (C_{10} for VLA batteries; C_8 for VRLA batteries; C_5 for Nickel Cadmium batteries)	Ah
2	Selected Discharge time / t_{table}	h
3	Selected Discharge current (from Discharge Tables) / $I_{discharge}$	A
4	Expected Discharged capacity / $C_e = I_{discharge} \times t_{table}$	Ah
5	Minimum cell voltage (from Discharge Tables)	V
6	Has the battery been fully charged	Yes/No
7	Cell Temperature before start of discharge	°C
8	Time discharge started / t_{start}	hh:mm
9	Time discharge stopped / t_{end}	hh:mm
10	Discharge duration / $t_{discharge} = t_{end} - t_{start}$	h
11	Achieved Capacity / $C_{test} = I_{discharge} \times t_{discharge}$	Ah
12	Achieved Capacity / $C = C_{test}/C_e \times 100$	%
13	Discharge log sheets completed	Yes/No
14	Battery passed the discharge test?	Yes/No

Remarks:

IEC 60623 Tests and requirements for vented nickel-cadmium prismatic secondary single cells

IEC 60896 Tests and requirements for VLA and VRLA prismatic secondary single cells

Done by Contractor	**Signature**	**Date**
Approved by Eskom	**Signature**	**Date**

Annex G – Vented Lead Acid Battery Commissioning Sheets

Eskom	VENTED LEAD ACID BATTERY COMMISSIONING SHEET	Sheet number		
			of	

Project / Works Order / Task Order No :		**Date &Time:**			
Site Name:		**Charge 1)**		**Discharge 1)**	
Battery Manufacturer:		**Model:**			
Manufacturing Date:		**Ambient Temperature [°C]**			

Charging Voltage [V]		**Charging Current [A] 1)**		**Pilot Cells Electrolyte Temperature**	**#**				
		Discharge Current[A] 1)			**[°C]**				

#	Volts	SG	#	Volts	SG	#	Volts	SG	#	Volts	SG
1			27			53			79		
2			28			54			80		
3			29			55			81		
4			30			56			82		
5			31			57			83		
6			32			58			84		
7			33			59			85		
8			34			60			86		
9			35			61			87		
10			36			62			88		
11			37			63			89		
12			38			64			90		
13			39			65			91		
14			40			66			92		
15			41			67			93		
16			42			68			94		
17			43			69			95		
18			44			70			96		
19			45			71			97		
20			46			72			98		
21			47			73			99		
22			48			74			100		
23			49			75			101		
24			50			76			102		
25			51			77			103		
26			52			78			104		

Comments / Remarks: 1) Sheet to be used for both charging and discharge cell data logging, tick correct box		Capacity charged [Ah]: Capacity discharged[Ah]:
Done by	**Signature**	**Date**

Annex H – Valve Regulated Lead Acid Battery Commissioning Sheet

Eskom	**VALVE REGULATED LEAD ACID BATTERY COMMISSIONING SHEET**	Sheet number		
			of	

Project / Works Order / Task Order No.:		**Date & Time:**			
Site Name:		**Charge 1)**		**Discharge 1)**	
Battery Manufacturer:		**Model:**			
Manufacturing Date:		**Ambient Temperature [°C]**			

Charging Voltage [V]		**Charging Current [A] 1)**		**Block**	**2V**		**6V**		**12 V**	
		Discharge Current[A] 1)								

String 1			**String 2**			**String 3**			**String 4**		
String Voltage [V]			String Voltage [V]			String Voltage [V]			String Voltage [V]		
String Current [mA]			String Current [mA]			String Current [mA]			String Current [mA]		
#	**Volts**	**Temp [°C]**	**#**	**Volts**	**Temp [°C]**	**#**	**Volts**	**Temp [°C]**	**#**	**Volts**	**Temp [°C]**
1			1			1			1		
2			2			2			2		
3			3			3			3		
4			4			4			4		
5			5			5			5		
6			6			6			6		
7			7			7			7		
8			8			8			8		
9			9			9			9		
10			10			10			10		
11			11			11			11		
12			12			12			12		
13			13			13			13		
14			14			14			14		
15			15			15			15		
16			16			16			16		
17			17			17			17		
18			18			18			18		
19			19			19			19		
20			20			20			20		
21			21			21			21		
22			22			22			22		
23			23			23			23		
24			24			24			24		
25			25			25			25		

Comments / Remarks: 1) Sheet to be used for both charging and discharge cell data logging, tick correct box		Capacity charged [Ah]: Capacity discharged[Ah]:
Done by	**Signature**	**Date**

Annex I – Nickel Cadmium Battery Commissioning Sheet

Eskom	NICKEL CADMIUM BATTERY COMMISSIONING SHEET	Sheet number		
			of	

Project / Works Order / Task Order No.:		**Date & Time:**			
Site Name:		**Charge 1)**		**Discharge 1)**	
Battery Manufacturer:		**Model:**			
Manufacturing Date:		**Ambient Temperature [°C]**			

Charging Voltage [V]		**Charging Current [A] 1)**		**Pilot Cells Electrolyte Temperature**	**#**				
		Discharge Current[A] 1)			**[°C]**				

#	Volts	#	Volts	#	Volts	#	Volts	#	Volts	#	Volts	#	Volts	#	Volts
1		26		51		76		101		126		151		176	
2		27		52		77		102		127		152		177	
3		28		53		78		103		128		153		178	
4		29		54		79		104		129		154		179	
5		30		55		80		105		130		155		180	
6		31		56		81		106		131		156		181	
7		32		57		82		107		132		157		182	
8		33		58		83		108		133		158		183	
9		34		59		84		109		134		159		184	
10		35		60		85		110		135		160		185	
11		36		61		86		111		136		161		186	
12		37		62		87		112		137		162		187	
13		38		63		88		113		138		163		188	
14		39		64		89		114		139		164		189	
15		40		65		90		115		140		165		190	
16		41		66		91		116		141		166		191	
17		42		67		92		117		142		167		192	
18		43		68		93		118		143		168		193	
19		44		69		94		119		144		169		194	
20		45		70		95		120		145		170		195	
21		46		71		96		121		146		171		196	
22		47		72		97		122		147		172		197	
23		48		73		98		123		148		173		198	
24		49		74		99		124		149		174		199	
25		50		75		100		125		150		175		200	

Comments / Remarks: 1) Sheet to be used for both charging and discharge cell data logging, tick correct box		Capacity charged [Ah]: Capacity discharged[Ah]:
Done by	**Signature**	**Date**

Annex J – Vented Lead Acid Battery Cadmium Sheets

Eskom	VENTED LEAD ACID BATTERY CADMIUM SHEET	Sheet number		
			of	

Project / Works Order / Task Order No :		**Date &Time:**	
Site Name:			
Battery Manufacturer:		**Model:**	
Manufacturing Date:		**Ambient Temperature [°C]**	

Charging Voltage [V]		**Charging Current [A]**		**Pilot Cells Electrolyte Temperature**	**#**				
					[°C]				

#	Positive	Negative	#	Positive	Negative	#	Positive	Negative	#	Positive	Negative
1			27			53			79		
2			28			54			80		
3			29			55			81		
4			30			56			82		
5			31			57			83		
6			32			58			84		
7			33			59			85		
8			34			60			86		
9			35			61			87		
10			36			62			88		
11			37			63			89		
12			38			64			90		
13			39			65			91		
14			40			66			92		
15			41			67			93		
16			42			68			94		
17			43			69			95		
18			44			70			96		
19			45			71			97		
20			46			72			98		
21			47			73			99		
22			48			74			100		
23			49			75			101		
24			50			76			102		
25			51			77			103		
26			52			78			104		

Comments / Remarks:		Capacity Charged :
Done by	**Signature**	**Date**

Annex K – SG adjustment examples

Example 1:

Consider the adjustment of SG from 1,240 to 1,250 in a FHP19 cell, using topping-up acid of 1,400. The assumptions are that all the electrolyte temperatures are 25°C and that the electrolyte levels are on “MAX”.

S1 = 1,240

V1 = 26,8 litres (Read from manufacturer specification sheet)

C1 = 32,6 (Read from table in Annex M)

S2 = 1,400

V2 = To be calculated

C2 = 50,5 (Read from table in Annex M)

C3 = 33,8 (Read from table in Annex M)

Temperature correction of the SG values is not required as they are already at 25°C.

From the problem statement, we deduce that we need to adjust the SGs *upwards*. Use equation 1) from section 4.6 to calculate the amount of electrolyte to remove from the cell and the amount of topping-up acid to replace it with.

From 1):

$$V_2 = \frac{S_1V_1(C_3 - C_1)}{S_2(C_2 - C_3) - S_1(C_1 - C_3)}$$

$$= \frac{(1{,}240)(26{,}8)(33{,}8 - 32{,}6)}{1{,}400(50{,}5 - 33{,}8) - 1{,}240(32{,}6 - 33{,}8)}$$

= 1,62 litres

Example 2:

Consider the adjustment of SG from 1,260 to 1,250 in a FCP13 cell, using de-ionised water. The assumptions are that all the electrolyte temperatures are 25°C and that the electrolyte levels are on “MAX”.

S1 = 1,260

V1 = 4,6 litres (Read from manufacturer specification sheet)

C1 = 35,0 (Read from table in Annex M)

S2 = 1,000

V2 = To be calculated

C2 = 0 (Read from table in Annex M)

C3 = 33,8 (Read from table in Annex M)

Temperature correction of the SG values is not required as they are already at 25°C.

From the problem statement, we deduce that we need to adjust the SGs downwards. Use equation 1) from section 4.6 to calculate the amount of electrolyte to remove from the cell and the amount of de-ionised to replace it with.

From 1):

$$V_2 = \frac{S_1V_1(C_3 - C_1)}{S_2(C_2 - C_3) - S_1(C_1 - C_3)}$$

$$= \frac{(1{,}260)(4{,}6)(33{,}8 - 35{,}0)}{1{,}000(0 - 33{,}8) - 1{,}260(35{,}0 - 33{,}8)}$$

= 0,2 litres

Example 3 (Temperature correction):

Consider the adjustment of SG from 1,240 @ 15°C to 1,250 @ 25°C in a FHP19 cell, using topping-up acid of 1,400 @ 15°C. The assumptions are that all the electrolyte temperatures are 25°C and that the electrolyte levels are on “MAX”.

Use equation 2) from section 4.6 to do temperature correction on all electrolyte SGs to bring it to 25°C.

Cell electrolyte SG @ 25°C = 1,240 – 0,007 = 1,233

Filling acid SG @ 25°C = 1,400 – 0.007 = 1,393

S1 = 1,233

V1 = 26,8 litres (Read from manufacturer specification sheet)

C1 = 31,7 (Read from table in Annex M)– interpolation may be required.

S2 = 1,393

V2 = To be calculated

C2 = 49,7 (Read from table in Annex M)

C3 = 33,8 (Read from table in Annex M)

From the problem statement, we deduce that we need to adjust the SGs *upwards*. Use equation 1) from section 4.6 to calculate the amount of electrolyte to remove from the cell and the amount of topping-up acid to replace it with.

From 1):

$$V_2 = \frac{S_1 V_1 (C_3 - C_1)}{S_2 (C_2 - C_3) - S_1 (C_1 - C_3)}$$

$$= \frac{(1{,}233)(26{,}8)(33{,}8 - 31{,}7)}{1{,}393(49{,}7 - 33{,}8) - 1{,}233(31{,}7 - 33{,}8)}$$

= 2,83 litres

Annex L – % Sulphuric Acid for a SG value at 25°C

SG	% H_2SO_4	SG	% H_2SO_4	SG	% H_2SO_4	SG	% H_2SO_4
1	**0**	1.225	30.8	1.355	45.8	1.485	58.8
1.1	14.7	1.23	31.4	1.36	46.3	1.49	59.2
1.105	15.4	1.235	32	1.365	46.9	1.495	59.7
1.11	16.1	1.24	32.6	1.37	47.4	1.5	60.2
1.115	16.8	1.245	33.2	1.375	47.9	1.505	60.6
1.12	17.4	1.25	33.8	1.38	48.4	1.51	61.1
1.125	18.1	1.255	34.4	1.385	48.9	1.515	61.5
1.13	18.8	1.26	35	1.39	49.5	1.52	62
1.135	19.4	1.265	35.6	1.395	50	1.525	62.5
1.14	20.1	1.27	36.2	1.4	50.5	1.53	62.9
1.145	20.7	1.275	36.8	1.405	51	1.535	63.4
1.15	21.4	1.28	37.4	1.41	51.5	1.54	63.8
1.155	22	1.285	37.9	1.415	52	1.545	64.3
1.16	22.7	1.29	38.5	1.42	52.5	1.55	64.7
1.165	23.3	1.295	39.1	1.425	53	1.555	65.2
1.17	23.9	1.3	39.7	1.43	53.5	1.56	65.6
1.175	24.6	1.305	40.3	1.435	54	1.565	66
1.18	25.2	1.31	40.8	1.44	54.5	1.57	68.5
1.185	25.8	1.315	41.4	1.445	55	1.575	66.9
1.19	26.5	1.32	41.9	1.45	55.5	1.58	67.4
1.195	27.1	1.325	42.5	1.455	55.9	1.585	67.8
1.2	27.7	1.33	43.1	1.46	56.4	1.59	68.2
1.205	28.3	1.335	43.6	1.465	56.9	1.595	68.7
1.21	29	1.34	44.2	1.47	57.4	1.6	69.1
1.215	29.6	1.345	44.7	1.475	57.8		
1.22	30.2	1.35	45.3	1.48	58.3		

Annex M – SG Adjustment Table

Desired SG @ 25°C	1.210	1.250
SG of adding acid @ 25°C	1.400	1.400
SG of water @ 25°C	1.000	1.000
End of charge SG	**ml / l**	**ml / l**
1.180	129.66	302.67
1.185	111.88	288.50
1.190	89.95	270.90
1.195	70.14	255.09
1.200	49.27	238.44
1.205	27.26	220.86
1.210	**0.00**	198.99
1.215	24.52	179.16
1.220	48.06	158.14
1.225	70.66	135.83
1.230	92.39	112.11
1.235	113.29	86.83
1.240	133.40	59.84
1.245	152.77	30.96
1.250	171.43	**0.00**
1.255	189.42	21.79
1.260	206.78	42.82
1.265	223.54	63.12
1.270	239.72	82.72
1.275	255.36	101.66
1.280	270.48	119.98
1.285	282.83	134.85
1.290	297.05	152.10
1.295	310.83	168.79
1.300	324.17	184.95
1.305	337.09	200.61
1.310	347.70	213.40
1.315	359.91	228.20
1.320	369.95	240.31

Annex N – Battery In/Out Commissioning Sheet

BATTERY IN/OUT COMMISSIONING SHEET

SUBSTATION ____________ DC Function ____________

Works order number ____________

OLD EQUIPMENT		NEW EQUIPMENT	
Decommission Date		Commission Date	
Battery Make		Battery Make	
Battery Type		Battery Type	
Order no		Order no	
ENC Contract no		ENC Contract no	
Rating		Rating	
Manufacture Date		Manufacture Date	
Lead acid/Nicad		Lead acid/Nicad	
Number of cells		Number of cells	
Type of stand/cubicle		Type of stand/cubicle	

Remarks ____________

Name ____________

Signed ____________

Tel no ____________ Responsible DC person ____________

Date ____________ Plant Manager ____________