Battery management

A guide from **Erie Aviation, Inc.**
1607 Asbury Road
Erie, PA 16509
T: 814-838 8934
F: 814-833 3672
www.erieaviation.com

Disclaimer
Our experience is very specifically with batteries made by Diehl Luftfahrt Elektronik (DLE) in Germany that power emergency power supplies on commercial aircraft, so that's what we'll talk about. You may be able to apply these ideas to other Nickel Cadmium (NiCd) batteries, but at your own risk. What we discuss here is grounded in the component maintenance manuals issued by DLE, the battery expertise of Cadex Electronics Inc. of Canada and our own 20-year history of servicing DLE batteries. This is a guide only. If you are responsible for signing off batteries as being serviceable there is no substitute for understanding and using the CMM and other information published by DLE.

General
All emergency power supplies are no-go items. In other words, they – and their batteries – must be in good working order for the flight to take off, so making sure the batteries are healthy can help avoid costly delays or even AOG situations. The batteries are also expensive, so getting the full life out of them is important for keeping maintenance costs in line.

The Diehl batteries we cover here
Any specific data referred to in this document is for the DLE 3214-30/-31 batteries. Although the general treatment of other DLE NiCd batteries is the same, please make sure to check the relevant CMM for specifics on charging currents, voltages, timing, etc., etc.

DLE chose the NiCd chemistry for their power supply batteries because of its reliability and many other advantages:

- Fast and simple charging procedures
- The high number of charge/discharge cycles compared to other chemistry types

- Their high discharge current
- Their long shelf life
- Simple storage and transportation
- Good performance also at lower temperatures

However, to get all this out of the batteries, they need to be properly maintained and used, which is also essential for coping with a couple of disadvantages:

- A high self-discharge rate
- The potential for reduced capacity from crystalline formation (see below on the "memory effect")

One process definition
When we talk about **reconditioning** a battery, we mean following the TESTING AND FAULT ISOLATION procedures in the CMM, or using the Cadex C7400ER Analyzer with the appropriate Diehl battery procedure (see Diehl SIL 3214-33-01/04 dated June 7, 2004)), or using the EAI single-battery charger EAI-CHG-04-01 according to its instructions. These methods will produce a fully charged battery ready to be installed or to go into refrigerated storage

Battery life definitions

- **Shelf life**. This is the expected lifetime of the battery, a combination of the time it spends in storage and in service in an aircraft. Diehl recommends that a battery be replaced after the expiration of its shelf life because of an increasing probability of battery failure after that date. The shelf life for the 3214-30 is 48 months and for the 3214-31 it is 60 months. The shelf life is less than the storage life and the service life combined, so if you want the full 36 months or more service life out of the battery, don't store it for too long – certainly not more than 24 months.
- **Storage life**. This is the maximum time you can store a battery following the CMM ASSEMBLY/STORAGE instructions and still expect it to function normally when putting it in service. For the 3214-30/-31 battery it is 36 months.
- **Service life**. This is the life expectancy of the battery when installed in an emergency power supply that is in service. For the 3214-30/-31 it is 36 months. There is no need to replace the battery after 36 months of service if it continues to function well, but the total shelf life should ideally not be exceeded.

Charging rates

- **The C-rate** is used to describe the charge rate for a battery. If you charge a battery rated 4Ah (4 Amp-hours) with 4A of current, you are charging at 1C. If you use 0.4A of current, you are charging at 0.1C. The term can also be used to describe the discharge rate of a battery.
- **Trickle charge** means you are simply maintaining the capacity of the battery by charging at a very low C-rate. All you want to do is compensate for the battery's self-

discharge. That means about 1/40 C (0.025 C) – or about 100mA for these DLE batteries.

- **Slow charge** means charging at 0.1C or in our case around 400mA. This is what has been in the CMM from the beginning – it is very safe, but takes a long time.
- **Quick charge** means charging at 1C or more. It is very fast, is used by the Cadex Analyzer and the EAI charger, but requires too close monitoring to be done manually.

Keeping track of your batteries
Depending on your operation, you may want to track your batteries by type/usage, part number and serial number. Record the manufacturing date in case of a warrantable failure and record what you do to the battery: dates and type of servicing (a booster charge when in cold storage or a full reconditioning) including the performance data, dates and types of storage or dates of installation in an aircraft or removal dates.

The BatteryShop 1 software from Cadex will not only do this for you in a very user-friendly manner, it will also help you manage up to 128 Cadex C7400ER Battery Analyzers.

What's a healthy battery?
One that passes a capacity test and has no visible damage.

What is a serviceable battery?
A serviceable battery, i.e. a battery ready to be installed in an aircraft and be operational immediately, will have retained at least 80% of its full charge (capacity).

What is a cap test?
This is a capacity discharge test. Steps (b) through (d) in the CMM procedure below describe it, and the tests built into the Cadex Analyzer and the EAI charger are similar. You must start with a fully charged battery, and the intent is to simulate how the battery will have to perform in an emergency on-board the aircraft to make sure it can do the job. So why is this important?

The Emergency Power Supply Unit (EPSU) or the Autonomous Standby Power Supply Unit (ASPSU) that the battery is connected to must ensure safe evacuation of the aircraft in an emergency. That means powering emergency lights (exit signs, floor escape path markings and external lights) for at least 15 minutes.

For the 3214-30/-31 battery that means providing 6.8 A for at least 15 minutes. A new battery can do this for about 35 minutes, so there is a good margin to allow for the reduced capacity of an ageing battery. However, to be on the safe side, DLE recommends disposing of batteries that can't provide full power for more than 24 minutes – roughly twice the required minimum. The way this is actually tested is to discharge the battery into a fixed load of 0.88 Ohm and monitor the voltage. It must be over 5 VDC for at least 15 minutes.

What is the self-discharge rate?
The self-discharge rate describes the capacity loss of a battery during storage. This capacity loss is caused by internal "leakage" between the positive and negative plates.

In general, a NiCd battery loses 10-15% of its capacity within 24 hours after a full charge and another 10% per month thereafter. The self-discharge rate will increase if the battery is stored at or above room temperature, doubling with every 10 deg-C (18 deg-F) rise in temperature. This is why storing batteries in a refrigerator is so important.

The self-discharge rate also increases as batteries get older and heavily used.

How should batteries be charged (reconditioned)?

1) **The traditional CMM method – cycle time about 29 hours**
   a) The battery should be at room temperature (64 to 82 deg-F or 18 to 28 deg-C) and the relative humidity should be less than 80%.
   b) To start, discharge the battery to 5 – 5.3 VDC:
      i) Connect the battery terminals to a 0.88 Ohm ± 2% load resistor (100 Watt size won't get uncomfortably hot) with a disconnect switch in series that's left open. Use DLE 774-026-73 contact pins to avoid damaging the battery's contacts.
      ii) Attach a digital multi-meter across the load resistor and close the circuit
      iii) Discharge the battery until it has reached 5 V. DLE advises against going much below the 5 VDC.
   c) Fully charge the battery:
      i) Set your DC power supply to 7.5 V (max 7.8 V) and the current limitation at 410 ± 10 mA.
      ii) Make sure the polarity of the power supply is correct (the wrong polarity can blow the power supply), and connect it to the battery, again using DLE 774-026-73 contact pins.
      iii) Switch on the DC power supply.
      iv) After 14 hours of charging, switch off the power supply and disconnect the battery.
   d) Do a capacity discharge test:
      i) Connect the battery terminals to a 0.88 Ohm ± 2% load resistor as described in point b above. The battery voltage must be at least 6 VDC!
      ii) Attach a digital multi-meter across the load resistor and close the circuit
      iii) On graph paper plot the voltage and time and stop the test when the voltage has reached 5 – 5.3 VDC (or use a printer/flatbed recorder).
      iv) A good 3214-30/-31 battery will take at least 15 minutes to go below 5.6 VDC.
   e) Charge the battery again following the same procedure as in point (c) above.

2) **The Cadex method – cycle time about 4 hours**
   a) You can charge up to four batteries at the same time using the Cadex C7400ER Battery Analyzer, which is available from Erie Aviation, Inc. You also need up to four each of these adapters for connecting the batteries to the Analyzer:
      i) P/N 07-110-9650 for the 3117-01 battery
      ii) P/N 07-110-9200 for the 3214-30/-31

iii) P/N 07-110-9660 for the 3301-31.

b) There is a large number of other adapters available as well as the FlexArm universal adapter, so you can use the C7400ER to service a very broad range of NiCd, NiMH, Li-ion and other batteries – for instance those in your ground radios.
c) The C7400ER can operate as a stand-alone unit and you can connect both a label printer or a regular parallel printer to it. You can also connect it to a PC running the BatteryShop 1 software from Cadex. The standard license lets you connect up to 3 Analyzers to a PC. Other licenses are available for up to 128 Analyzers.
d) The battery should be at room temperature (64 to 82 deg-F or 18 to 28 deg-C) and the relative humidity should be less than 80%.
e) Turn the Analyzer on and connect the adapter cable to an available charging slot.
f) If you are not connected to a PC running the BatteryShop 1 software: Push the button for this charging slot and select: **AUTO**. Insert the battery in the adapter. The Analyzer will go through a cycle similar to that of the CMM, first charging the battery (but at the much faster rate of 3A), then discharging it, doing a cap test (using a constant amperage discharge circuit vs. the constant resistance circuit of the CMM), and then charging it. If the battery fails the cap test (i.e. has less than 80% of its full capacity), it will be given a deep discharge, then charged, then given one more cap test. If it passes, it will be given a final charge. A **green light** indicates pass, and the capacity is displayed on the LCD. If it fails, a **red light** will indicate this along with a fail message on the LCD – and the battery should be disposed of.
g) If you use the BatteryShop 1 software with its original settings for the DLE batteries, start the **AUTO** program from the PC (the unit's pushbuttons are not active).When it states "Ready to accept batteries" insert the battery into the adapter. The Analyzer will go through the same steps as in f) once a battery is inserted.
h) Upon completion the Analyzer will provide a trickle charge to the battery.
i) You can run up to 4 batteries simultaneously, but they don't have to start at the same time or even be of the same type. Each charging slot is fully independent..
j) At the end you may print a label for the battery and/or a full service report.

3) The EAI charger – cycle time about 4 hours

a) The reconditioning process of the EAI-CHG-04-01 closely resembles the CMM procedure as it discharges into constant resistance load, but it is automated and much faster. It will handle one DLE 3214-30/-31 battery at a time.
b) Connect the charger to power (110-240VAC) and turn it on.
c) The battery should be at room temperature (64 to 82 deg-F or 18 to 28 deg-C) and the relative humidity should be less than 80%.
d) Mount the battery in the charging slot and using the toggle-switches on the charger, select **RECONDITION**.
e) If the battery voltage is less than 6 VDC, the full charge cycle will take about 4 hours and has these steps:
   i) Discharge the battery to 5 V using a 0.88 Ohm ± 2% constant load resistor
   ii) Charge for about 90 minutes at 3A (0.75C)
   NOTE – When charging at the 3A rate, the EAI charger will stop if
      - the battery voltage starts to drop at any time during the charge ("negative ΔV", or

- the battery housing temperature exceeds 45 deg-C (113 deg-F), or
- the running time exceeds 90 min

iii) Do a timed discharge test (cap test) to ensure the battery meets the 5.6 V minimum in 15 minutes. The discharge will continue until the battery reaches 5 VDC.
iv) Do the final charge, again for about 90 minutes at 3 A
v) The charger will signal failure at any point in the process and stop there.

f) If the battery voltage is above 6 VDC, the charger will do a cap test and then charge the battery. This will take about 2 hours and has these steps
   i) Do a timed discharge test to ensure the battery meets the 5.6 V minimum in 15 minutes, continuing until the battery reaches 5 VDC
   ii) Do the charge for about 90 minutes at 3 A
   iii) The charger will signal failure at any point in the process and stop there.

The EPSU as a battery charger
The Emergency Power Supply will make sure that its attached battery stays fully charged, but it can only do so when aircraft power is available and there is no power demand on the EPSU itself. For instance, if the emergency lights powered by the EPSU are on, they must be turned off and aircraft power must be available to the EPSU for sufficient time to recharge the battery – typically about 35 minutes for an EPSU with a quick-charge feature built in. The EPSU can also be instructed to do a cap test through the CIDS, but again, the EPSU must be given sufficient time to complete the discharge and charge. If you need to replace a failed battery and you only have a discharged, but otherwise healthy battery available, you can bring it up to full charge by placing it in an EPSU for about 30 minutes with aircraft power available.

You can also use an EPSU as a battery charger in the shop by connecting it to 28 VDC, but we don't recommend it. First, the EPSU is too expensive for this; second, the connections you need to make are complicated.

Can you quick-charge a battery?
Yes, that is what the Cadex Analyzer and the EAI charger do, and also what the EPSU does. However, we do not recommend manually quick-charging these batteries – there are too many variables to monitor, and if the operator gets distracted, the battery can easily be ruined.

How to store a charged (serviceable) battery
Unfortunately, NiCd batteries have a fairly high self-discharge rate and lose their charge gradually when they are stored – relatively quickly if stored at a high temperature on a warehouse shelf, more slowly if stored in a controlled environment. Depending on the ambient temperature in the warehouse (or during transit), a fully charged battery may fall below the serviceable voltage level in a week or less. Stored at +32 to +50 deg-F (0 to +10 deg-C) in a refrigerator, it will lose only 10-20% over two months. In other words, if you need to have immediate availability of serviceable batteries, store them in a refrigerator near or at the service location. No special packaging is required, but we don't recommend freezing

the battery. Let the battery return to room temperature before installing it and wipe off any condensation.

This is how we do it for our own test batteries:

> We start with a quantity of fully charged batteries, place them all on one shelf in a fridge kept at about 36 deg-F (+2 deg-C). We mark the shelf with a re-charge date that's two months down the road. When that day arrives, we take the batteries out, let them return to room temperature and give them a booster charge of 410mA ±10 mA each for three hours ($U_{Bat.max}$ = 7.5 to 7.8 VDC), put them back in the fridge and change the date on the shelf to two months ahead. Check the voltage of each battery both before and after the boost to make sure it is good. If the voltage has dropped more than expected during storage (more than 20%), recondition that battery according to the CMM or with the Cadex or EAI chargers.
>
> > If you use the Cadex Analyzer, select the **CHARGE** program
> >
> > If you use the EAI charger, select the **BOOST/FAST** program
>
> We also mark each battery with the date when it was first placed in cold storage so we can use batteries on a FIFO (first in, first out) basis. A battery should go through a full reconditioning after 12 months in storage.

An operator treating the EPSU and battery as a single inventory unit can seal this in a plastic bag and put it in the refrigerator – essentially treat the whole as you would just a battery. The plastic bag is there to prevent condensation inside the EPSU and must be kept closed while the unit gets back to room temperature. And by the way, a stored EPSU will not drain the battery beyond the battery's self-discharge rate. The battery is not electrically connected until the main connector is hooked up – this includes the battery bridge

Does trickle-charging work for storage?
Storing batteries while connected to a trickle charger also works (a DC power supply with 90-110 mA output at 7.5-7.8 V per battery), but because this can shorten the life of the battery, it is not recommended for extended storage. 6 months is the maximum, at which point the battery needs to go through a complete reconditioning, again using either the manual CMM method or the Cadex or EAI chargers.

If you store the battery and the EPSU together, a trickle-charging alternative is to connect the EPSU to a 28 VDC power supply with the battery securely mounted, and let the EPSU keep the battery charged, just as it would in an aircraft. We recommend reconditioning the battery after 6 months.

How to store an uncharged battery
A NiCad battery can be stored in an un-charged state for a long time at normal warehouse temperature – generically for 5 years or more although DLE does not recommend more than 3 years and suggest that less is better. A DLE battery should be fully charged, then

discharged to a level of about 1 V per cell (i.e. 5 V for a 3214-30/-31) before being put away for long-term storage. A new battery supplied from DLE via EAI can be put away for long term storage as is. When you need to use a battery that has been stored for a long time, it needs to be **"primed"**. That means that the first charge needs to be slow, no more than 0.1C (i.e. max 400 mA), as in the manual CMM procedure, followed by 2-3 discharge/charge cycles at the quick-charge rate of 1C (or 4 A).

> The Cadex program you select for that is **ExtPrime**. This will take the battery through a trickle/slow charge (at 200mA) for 16 hours and then cycle it through the **PRIME** program until the battery has reached its optimum voltage. This will take about 20 hours all told.
>
> With the EAI charger you run a **SLOW** charge once (this will take about 14 hours at 400 mA) and then run the **RECONDITION** program a couple of times
>
> These programs are designed to maximize battery life and performance. If you don't have that much time available, a normal AUTO charge cycle on the Cadex Analyzer or RECONDITION on the EAI charger will both give you a serviceable battery.

If you put away a fully charged battery, the result will likely be crystalline formation in the cells as the battery gradually self-discharges. This will significantly reduce its capacity until it can be fully reconditioned.

Getting new batteries ready for use

A new battery must be **"activated"** - charged correctly – before its first use. Few things will have as positive an impact on its life as that. When you buy a new DLE battery, it is supplied in an unserviceable state with only a minimal charge. Correct activation means conducting a charge/discharge cycle three times in a row using one of these methods:

> Using the manual CMM method by charging at 410 mA ± 10 mA for 14 hours. Check the battery voltage beforehand. If – against expectation – it is above 5 VDC, discharge the battery to 5 V before charging. Repeat twice.
>
> Plug the battery into the Cadex Analyzer and select the **PRIME** program. If the battery voltage is really low, the Analyzer may not recognize it. In that case, press and hold the bay's activation key for 3 seconds. This will automatically run a brief **BOOST** program before returning to the PRIME program (or whatever program you had selected from the BatteryShop 1 menu)
>
> Use the **RECONDITION** option on the EAI charger 2 or 3 times

What is 'memory' in a NiCd battery?

Modern NiCd batteries do not show measurable 'memory' – short for cyclic memory – in the sense that they will remember the amount of energy that was discharged earlier, before a recharge, and then only be able to discharge that amount of energy the next time. The real problem is with crystalline formation. The small Cadmium crystals in the battery gather into

larger crystals with much less surface area, which means a loss of capacity, possibly even total battery failure. When you have shallow (partial) discharges followed by a charge, only a portion of the battery's active material is involved in the process. The Cadmium crystals not involved tend to form larger crystals. Several charge/discharge cycles or a single deep discharge using a Cadex analyzer may correct the problem

Can batteries be repaired?
By "repair" we mean correcting physical damage to the battery, such as a cracked housing, damage to the internal wiring, etc. The older 3214-30 and 3117-01 batteries are repairable. The newer 3214-31 is a sealed unit and can consequently not be repaired, but it can obviously be reconditioned as we have used the term in this paper.

What is the warranty coverage for Diehl batteries?
The warranty coverage provided by DLE for their Airbus batteries is 36 months. For some other aircraft makes it may be shorter, so please contact us if you believe you have a warrantable failure.

When do you need to replace a battery?
The short answer is "when it stops working" or when it is physically damaged. If it fails the capacity discharge test after having been fully charged, you should replace it. A second reconditioning could bring the battery up to a serviceable level, but it may lose its charge much faster than a new, healthy battery will, and that can mean a delayed flight. This is typically the case with older batteries (5 years +).

Disposing of batteries
Cadmium is a pollutant, so make sure you follow local ordinances when disposing of the batteries. However, NiCd batteries are not "hazardous", so there are no storage or shipping restrictions.

Shipping batteries
When EAI sells you a new Diehl battery, it is not (fully) charged and it is your responsibility to make sure it is serviceable before it gets installed (see **New Batteries** above). When we ship you a battery we have serviced for you, it typically leaves our facility fully charged, but because we cannot control the duration or the conditions of the shipment, we cannot guarantee that it will arrive in a serviceable state. Chances are good it will be OK, but if it is exposed to high temperatures or is delayed, it may arrive with a less than a serviceable charge. If you need to make sure it will be immediately serviceable – and you know it left EAI in a fully charged state per the 8130 – we suggest you give the battery a boost charge (400 mA for 3 hours) and then store it in a refrigerator.

Use genuine DLE batteries only!
The aircraft was certificated using genuine Diehl batteries as an integral part of the emergency power supplies. For this reason, Diehl cannot guarantee the performance of these critical components if a different battery is used. Airbus has arrived at the same conclusion for the DLE power supplies on their aircraft. See the Airbus circular telex "OIT SE999.0035/04/BB" issued on March 23, 2004.

Additional information sources:

Diehl Luftfahrt Elektronik GmbH:

CMM 33-51-05 covering battery P/N 3117-01
CMM 33-51-07 covering battery P/N 3214-30
ACMM 33-51-17 covering battery P/N 3214-31
CMM 33-50-01 covering ELPU P/N 3400-22 including the battery P/N 3301-31
Customer Information Letter dated September 2, 2002
Service Information Letter (SIL) 3214-33-01/04 dated June 7, 2004

Cadex Electronics Inc.:

Batteries in a Portable World (2nd edition)
- a handbook on rechargeable batteries for non-engineers
by Isidor Buchmann, President & CEO, Cadex Electronics Inc
www.cadex.com

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This guide was written and conceived by Erie Aviation, Inc. personnel, who received great guidance and editing help from the people of Diehl Luftfahrt Elektronik GmbH and Cadex Electronics Inc.

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