

Battery Testing Made Easy

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Introduction:

Battery testing of aircraft Nickel-Cadmium batteries is a complex process but it does not have to be complicated. The tests in themselves are not complicated but they do require very strict attention to details to insure that the process will be accurate and efficient.

Accuracy is fundamental because battery testing is an exact process. There are tangible numerical limits¹ that determine pass fail conditions. Efficiency is fundamental because battery testing, being a laborious process, requires a careful choice of process and equipment that will permit meeting the manufacturer's requirements while minimizing the expenditure in equipment and personnel.

In order to meet the accuracy and efficiency requirements I will focus on the two most relevant aspects of the battery testing: Equipment and Process.

Equipment comprises the Charger-Analyzer and a variety of accessories such as meters, resistors and shorting clips, plus water dispensers and syringes. The Process on the other hand, comprises all the procedures and individual steps that must be followed to meet the battery testing requirements.

Types of Tests:

Battery testing focuses on two basic types of tests: charge acceptance and capacity.

Charge acceptance is the ability of the battery to convert input current into charge in the plates, as evidenced by voltages developed across the terminals of each of the cells and the overall battery voltage, each one within limits established by the manufacturers²

Capacity is the ability of the battery to deliver the rated current for a minimum time while the overall battery voltage and that of each individual cell remains above minimum set voltages.

Equipment:

Although any form of charging can be used to charge a battery and any form of load can be used to test a battery, it must be pointed out that battery performance testing requires exacting conditions of current, voltage, time and temperature, hence, establishing the need for precision performance³.

The most important performance characteristic of the Charger-Analyzer for Nickel-Cadmium batteries is constant current⁴ because that is the best (only) way to determine charge acceptance and capacity and it is how testing is specified by the battery manufacturers. Although other charge methods are mentioned, the only method that is fully described by battery manufacturers is constant current. Hence, the method of choice.

Most Nickel-Cadmium batteries require a two step constant current charging process. The first one, called Main, is used to replenish the charge taken out during the Capacity Test and the second one, called

¹ As provided by battery manufacturers in their manuals and individual battery specifications (CMMs) and include: individual cell voltages (min and max), overall battery voltage (min and max), time and temperature.

² Note that battery temperature is also a limiting factor in the charge acceptance criteria.

³ Battery Charger-Analyzers are precision instruments and not simple chargers.

⁴ Constant Current means that the charging current will remain at the established value independent of battery voltage, line voltage and other factors.

Topping, is to “top-off”⁵ the battery and to test that each of the cells reaches the proper charge voltage⁶. It is during this Topping Charge period that temperature must also be observed⁷. In addition, at the end of the Topping Charge period, the level of the electrolyte is verified and distilled water added as needed.

Additional characteristics required of Charger-Analyzers include intuitive and user friendly programming of the test parameters such as current, time and battery voltage/number of cells, all with the necessary accuracy and stability for the validity of the tests⁸. When controls are easy to understand and use, training time is reduced and the chances of erroneous settings are also reduced. In addition, the equipment must be intrinsically safe for the protection of the operator, the battery and the instrument itself⁹.

Process:

The Process for battery testing is straightforward but it is laborious, requiring great attention to detail.

Testing procedures are well defined by manufacturers in their manuals (OMM¹⁰) and individual battery data sheets (CMM¹¹), so the only special requirement is the selection of the equipment to properly meet the test requirements. As stated above, the choice of equipment will determine how well the test requirements are adhered to and, as described further, how much work will be required by the operator.

Note that failing to observe proper testing requirements can and will result in premature failures and/or unnecessary replacement of batteries and cells, both having a significant impact in the cost of battery maintenance and in the operation of the aircraft. Improper battery maintenance can easily result in costly AOG situations and scary in-flight battery emergencies¹².

Battery testing is laborious because of the many steps that are required. From the readings taken to determine the “as received” condition, to the multiple cycles of charge and discharge required to restore the capacity of the cells, there is a requirement for a multiplicity of measurements and record keeping.

The most involved part of the testing is the multiple measurements that must be performed. For a typical 20 cell Aircraft Nickel-Cadmium battery this means twenty measurements of cell voltages in addition to the battery voltage at its terminals for every step in the test process.

Although readings at the end of the charge and discharge tests constitute the bottom line for pass/fail determination, intermediate readings are fundamentally useful because they provide early warnings of impending failures and/or they provide historical information that can be used to explain observed cell failures¹³.

⁵ The charge process is not only not 100% efficient, it drops as the cells charge up. Therefore, it is always necessary to deliver more charge than has been taken out to insure a full charge, typically 40% more, for a total of 140%.

⁶ Cells that do not develop the proper charging voltage could indicate a failure of the separator or simply that they are insufficiently charged. Furthermore, cells that do develop a proper voltage but later show a drop do so because of separator failure (there is also a temperature rise associated with separator failure).

⁷ Nickel-Cadmium batteries are not expected to warm-up significantly during the charge process. If they do, it could mean that the cell separators are failing or that the internal resistance of the cells is high (worn out cells) or that the battery is being overcharged.

⁸ Immunity to power input fluctuations and power input interruptions is also necessary. Most tests require hours of operation hence the need for safeguarded unattended operation.

⁹ This includes overcurrent limiters, temperature cut-offs and other types of protection.

¹⁰ OMM: Operating Maintenance Manual

¹¹ CMM: Component Maintenance Manual

¹² Overheating (requiring that the battery be disconnected from the bus) and low reserve power in case of power failures are the most common in-flight battery problems.

¹³ Note that the measurement of all cell voltages is not optional. It is a fundamental part of battery testing requirements and it is well specified in battery manuals and individual data sheets.

The end result is that even without intermediate readings, a typical battery test sheet can have one hundred or more individual readings. Clearly, this is a source for transcription errors in addition to the tediousness of measuring and recording.

Automating the process:

As stated in the introduction, there are two fundamental parts of the battery testing process: the equipment to charge and discharge the batteries and the measurement of battery and cell voltages.

Although there are opportunities for automation at both ends, automating the process of measuring battery and cell voltages is definitely the most important one, for it alleviates the problem of time consuming and error prone manual measurements and recording.

Automation of the charge/discharge process, on the other hand, is not as important because individually it is a lengthy process, particularly in the charge cycle which could take up to six hours per test. It would be desirable to achieve a total hands-off operation where the battery goes through its total testing on a “non-stop” basis. But, this is basically not possible because of a variety of limitations. First of all, it is not possible to go from one test to another without reviewing the results. All results, all cell readings that is, not just battery terminal voltage, must be evaluated (temperature included) to determine if the battery is ready for the next test. Depending on the readings it may be necessary to replace one or more cells and/or alter the test process. In addition, a battery that has just completed a capacity test or total discharge will be hot and has to be allowed to cool down prior to recharging it¹⁴.

It is possible, however, to increase the efficiency of the charge/discharge process with equipment that can physically charge/discharge more than one battery at a time.

Cell Measurement Automation:

As stated in other parts of this article, battery performance is dependent on the performance of each cell and not as the sum total measured at the battery terminals. Therefore, automation of the measurement of each of the cells is the basis for a battery analysis system. Furthermore, it is not simply about automating one time readings but to produce continuous readings throughout the test process.

Cell readings need to be automated no just simply to eliminate errors of manual readings but also to insure that all measurements are taken at the same time. With manual measurements, from the reading of the first cell to the last cell, more than one minute can easily elapse. This is of particular importance during the Capacity Test because when cells are at the end of their discharge capacity, cell voltages will fall rather quickly thus resulting in significant variations from the first cell to the last.

With cells that have ample reserve capacity this may not be that important but with marginal cells, it can mean that the first cells being read may pass but the last ones may not resulting in an inaccurate picture of battery performance.

Continuous readings are needed so that a more complete picture of the test profile can be obtained. Cells can fail at any time, during charge as well as during discharge.

¹⁴ As stated earlier, a Nickel-Cadmium battery must not exhibit temperature rise during charge for it is a sign of cell separator failure, worn out cells, overcharge, etc. Therefore, if the battery is hot to begin with, it will not only mask-off internal problems, it will also prevent cells from reaching the proper charge voltage (cells will not reach the expected charge voltage if hot).

In the charge process a failure of the cell separator can show up at any time: a drop in voltage with or without an increase in cell temperature. Visualizing this, particularly early in the test cycle, can simplify the analysis of the performance and can reduce unnecessary, time consuming testing.

Electronic Storage of Cell Measurements:

When data is recorded and not just printed as a one-time measurement, it is possible to develop a history for a particular battery that allows for comparison of tests performed throughout the life of the battery. Comparing a recent Capacity Test with a prior one can help determine the true health of the battery and can even be used to “predict” immediate and future needs for cell replacements.

It is a common practice to salvage “good” cells from several batteries and from that to assemble one “good” battery. To accomplish this, it is necessary to know the history of performance of each of the cells so that some degree of matching can be achieved. With recorded data, it is perfectly possible to achieve this with a high degree of confidence.

Finally, there is always the need for traceability and if data is archived electronically it makes it much easier to retrieve it at a moment’s notice.

The Total Solution:

The total solution to achieving accuracy and efficiency in the testing of aircraft batteries is to have an integrated system where the battery test equipment (Charger-Analyzers) are totally integrated and automated in conjunction with the Data Acquisition and Analysis System. As a bonus, not having to continuously watch tests in progress allows for personnel to perform other tasks, knowing that when they come back to the Battery Shop all data will be taken and ready for analysis.

With such a capability, the process of battery testing can easily become a manageable process and not a nightmare.

What JFM Engineering offers as the Total Solution:

JFM Engineering offers the BTAS16 system for the automation of data in the battery shop as well as a variety of Precision Charger-Analyzers capable of testing Nickel-Cadmium, Lead-Acid and other types of rechargeable batteries, from small packs for emergency power back-up, to main batteries used for the starting of engines or the APU¹⁵.

The main component of JFM's automation solution is the BTAS16. It is a system designed specifically for the automatic reading of battery voltages, cell voltages, charge/discharge currents and battery temperature, and for the presentation, analysis, reporting and archive of the information in a desktop computer.

The BTAS16 system can receive information from an array of up to sixteen data terminals (called C-Scan) and can in turn, provide limited monitoring and control of specially modified Charger-Analyzers such as the Superseder III and 24-400T and direct monitoring and control of the new line of XG Charger-Analyzers (Superseder and 24-400) and also the SuperMasterCharger and miniMasterCharger.

An assortment of battery specific crowns and universal leads with clips provide the electrical input to the C-Scans while auxiliary connections read the charge/discharge current, measure battery temperature (through a Temperature Plate) and monitor and control the Charger-Analyzers.

The end result is continuous measurements throughout the entire test cycle, that present to the operator a detailed view of the performance of the battery and of the Charger-Analyzer. In addition to basic tables of numeric results, the BTAS16 shows data in graphic format (voltage, current and temperature vs. time) with color coding in the bar graphs to highlight acceptable, marginal, and failing results.

The advantage of the BTAS16 system is that, after each of the tests have been started; it becomes a hands-off operation by eliminating the need to watch over each of the batteries under test. With this system, all the technician needs to do is to periodically look at the colors in the graphs in search for any abnormalities, thus freeing the technician to perform other tasks in the battery shop.

A variety of reports provide also printed records of the tests performed, suitable for record filing (audit trail) and presentation to the end user (work order summary).

Ultimately, all the data can be archived for review and comparison at any time.

For details on screens, reports and overall performance characteristics, see www.jfmeng.com (BTAS16)

The Charger-Analyzers offered by JFM Engineering are precision instruments designed to test batteries exactly as specified by the manufacturers of the batteries. In addition, they have ample protection to prevent damage to the batteries and to be intrinsically safe for the operator. www.jfmeng.com (Products)

The Superseder, in particular, is also designed for speedier operation for it is designed to handle more than one battery at a time (up to a total of 50 cells).

The Superseder can charge at maximum current up to 50 Nickel-Cadmium cells. This means that it can accommodate up to two 22 cell batteries, up to four 11 cell batteries and up to seven 7 cell batteries! In

¹⁵ APU: auxiliary power unit, a turbine driven generator used to provide electrical power while the aircraft is on the ground and in case of in-flight power generation failures.

discharge it can also accommodate multiple batteries but at a reduced current if the total number of cells is over 22¹⁶.

But, it is the combination of the Superseder Charger-Analyzer and the BTAS16 system that maximizes the efficiency of the operation, for it is not enough for the equipment to be capable of working on so many batteries at any one time if we still have to take manual readings!

The combination of the Superseder and 24-400 Charger-Analyzers, and the BTAS16 Battery Test and Analysis System, provide a comfortable and effective hands-off operation. Once the system is setup and running, the technician can now dedicate time to other tasks in the battery shop, confident that at the end of the programmed tests all data will be recorded and ready for review.

¹⁶ In case of multiple batteries, it must be remembered that the charger-analyzer only “understands” total voltage. This means that multiple batteries are seen and are treated as one battery. Therefore, the capacity test of multiple batteries requires close monitoring of the individual battery voltages. The BTAS16 solves this problem by providing the required close monitoring, not only of the batteries as a whole but all cells individually as well.

JFM Engineering has been specializing in the development and manufacturing of precision instruments for the testing of batteries for the past 30 years.

In addition, JFM Engineering has an FAA certified repair station for the testing and maintenance of aircraft batteries of all types.

For additional information, please contact the sales department at 305-592-2272 (FAX 305-594-4933) or visit our website www.ifmeng.com for complete information on our products and services.