THE VIDEO BATTERY HANDBOOK

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Anton/Bauer has distributed more than 150,000 copies of the Video Battery Handbook since its initial publication in 1993. As the definitive guide to the care and feeding of video batteries it has been used as a reference and as a teaching aid in film and video courses in many schools and universities.

This is the fourth revision of the VBH and we have made every attempt to relate the up to date information on the battery chemistries used by professionals on the latest equipment in the video industry today. This Handbook is not meant to be a technical primer on battery chemistry, but a guide for videographers to better understand one of the least understood, yet most essential elements of a portable video operation.

In the three decades since television cameras began to leave the studio, both video and battery technologies have dramatically improved. Yet the batteries remain invariably at the top of the list of issues with today's video operations.

Smaller, lighter, more powerful, less expensive - who hasn't heard these wishes from a battery user, or as claims from a battery manufacturer? In fact, in all portable equipment markets, batteries are the number one area in which customers would like to see improvements. In the computer and cellular telephone markets, requests for improvements in battery life (runtime) and weight/size come before processing speed and cellular coverage. Of course, the broadcast and professional video industry is no exception.

Today the boom in personal electronic devices – PDAs, MP3 players, cell phones with color LCDs and cameras, notebook computers – are all looking for improved power solutions. This search leads to headlines of new power sources – plastic batteries, exotic chemistries, super capacitors, even fuel cells.

If only these devices were the same as a professional video camera. Most new cell types address the size and weight issues for mobile communications and computing products. Rightfully so since the market size for these products are several orders of magnitude greater than all camcorders, consumer to broadcast, put together. The manufacturer who could design a cell to be used in a battery for notebooks and cell phones was designing a product for the largest growth markets the battery industry had ever seen. Size and weight are paramount in mobile communications and computing to the exclusion of all other considerations – like performance and life. Very seldom does anyone keep a cell phone long enough to require a new battery. The publicity these new technologies receive in mobile communications and computing make them seem like the answer to all battery problems.

Over the years, the quest for the "perfect" battery has led to many unsuitable battery types being marketed over the years - batteries of incorrect voltage, unsuitable size and insufficient packaging fail to meet the requirements of a video professional. But because these batteries were touted as "smaller, lighter, cheaper" and because the uninformed view is often that "a battery is a battery", these products were purchased thinking that they would be suitable for a professional. Many of these were brought up by equipment manufacturers from consumer products to allow the manufacturer to offer a turn-key camera package. Professionals soon found out that problems with these batteries were insurmountable. Terms like "memory" were coined to explain the inadequate operation of poorly designed and/or misapplied batteries.

Once invested in a poor power solution, users looked for ways to salvage their bad battery investments. For example, we are all familiar with the variety of rejuvenators, reconditioners, de-memorizers, revitalizers and other such gadgets marketed in an attempt to salvage the large inventories of NP batteries in the marketplace. Well after investing thousands of dollars and hundreds of hours of maintenance time on their NP batteries, users found out too late that poor design and misapplication problems never really go away. Thus, to this day an NP user typically carries up to 4 times the amount of batteries that should actually be needed and replaces them twice as often.

Ever since the NP battery was introduced on the first BetaCams, users were looking for a way to "fix" them. Over the years this futile effort unfortunately was like trying to fix a mis-registered camera by buying a new lens. (Ironically the NP battery, originally an audio battery 30 years ago, to this day survives in the industry mainly as an audio mixer battery due to its size and the low power requirements of audio receivers and mixers.)

The quest for the "Holy Grail" of portable power has taken its most recent turn in a great deal of hype surrounding the current state of fuel cell technology and the coming hydrogen economy. The viability of fuel cells in portable video is discussed later in a technical update.

Today the impression is that *all* batteries are, or at least should be, some exotic formulation... It is simply not so....

Let's get a perspective with some irrefutable facts:

(1) Outside of cell phones and notebook computers, whose power requirements are a fraction of the power demands of portable professional video, NiCd and NiMH cells account for about 70% of the world market in rechargeable batteries. It is simply so because no other chemistry is capable of providing the current carrying capability of nickel based cell chemistry.

(2) About 70% of the NiMH and lithium ion cells produced are manufactured in small sizes (AAA and small rectangular chewing gum stick sizes) for mobile communications and computing. These size cells are not adaptable for professional video applications. Their small size and high internal impedance make them useless for the power demands and environmental conditions of video field production.

(3) A typical notebook computer draws less than 1 amp (with hard drive and back lit color LCD screen) usually at 12 volts or about 10 watts.

(4) A typical cell phone draws less than 1/2 amp at typically 5 volts or around three 3 watts.

(5) Aside from power tool and video there are few other applications where the batteries are not integral to the equipment. In other words a typical cell phone battery or computer battery will see only one device in its entire life under relatively fixed operating ranges for load, temperature and charging.

Now let's understand some of the criteria for professional video batteries:

(1) Today's average camcorder draws about 24 watts in record; a professional mini-DV camcorder may draw as low as 18 watts. Many new non-linear camcorders as well as high definition cameras, draw almost double (45 watts or more) that of the average camcorder. (*Oddly enough 20-45 watts has been the power range of cameras for the last 15 years.)*

(2) Non-linear acquisition (disk, DVD, solid state memory) in theory require *infinite* runtime. First they typically have a long "boot up time" so that they run almost continually in practice. Second, since the recording can be selectively "saved" the camera can be recording constantly thus theoretically requiring a battery which lasts for as long as the camera can be in operation.

(3) The typical on-camera light used today draws 25-50 watts. The typical focusable or dimming type light will always draw 50 watts.

(4) New formats have recording times on a single medium of 60 to 120 minutes or more an increase of 3 to 6 times over 10 years ago. Therefore, the power necessary to record a single tape has increased by 3 to 6 times.

(5) Nearly 2/3 of the weight of a camcorder (with lens) is forward of the center of gravity point- typically the physical center line of the camera – therefore, most of the weight is in front of the camera. Balance NOT weight is an overriding ergonomic consideration on a camcorder. Not compensating for this forward weight has been determined as the cause of fatigue and back strain for cameramen. Although cameras are getting smaller and lighter, camera lenses always remain out front, thereby unbalancing the camera. A 3-5 pound (1.5-2.5kg) battery actually balances today's camcorders perfectly while a lighter battery will actually add to the fatigue factor.

(6) A typical professional video battery is often used on several pieces of equipment – cameras, monitors, editors, lighting – and often used by a number of different operators under an extremely wide range of operating conditions.

The answer to the question, "Why aren't all these new battery types used for my camcorder?", should now be clear: *A professional camcorder used by a video professional has very different power and ergonomic requirements than a cell phone, a digital pocket camera, an MP3 player or a PDA used by an accountant. If a portable enterprise wants to remain portable, then batteries – cost efficient, powerful, long lasting and reliable ones – will continue to be part of the logistics of a video operation.*

The following discussion concentrates on full size professional video cameras where the user has a choice of battery types and performance options.

This guide will discuss the elements essential in determining the proper battery and charger system for a modern professional video operation. We have included additional technical sections for those who wish a more in-depth explanation. Another section deals with the aspects of on-camera lighting, an important factor both in battery selection and quality video production.

VOLTAGE

There is ironically still confusion concerning the proper voltage battery for an application. The confusion is due to the popular but incorrect practice of referring to a battery or camcorder by a single voltage. References to a “12 volt battery” or a “12 volt camera” do not refer to average voltage, nor do they signify minimum or maximum voltage. These numbers are called ‘nominal’ ratings, which are merely convenient ‘names’ for these devices and have absolutely no relevance whatsoever to a specific application.

In actuality, every battery and every camera has a voltage *range* over which it operates. The process of matching the correct voltage battery to a piece of equipment simply requires that:

The full operating range of the battery must fall totally within the operating range of the equipment being powered.

The first step is to establish the accurate voltage range of your equipment. If you have the instruction or technical manual, turn to the specification section and find the ‘Power’ entry. Hopefully you will find one of the following type entries:

VOLTAGE = 11-17 volts or VOLTAGE = 12(-1,+5) volts
OR
POWER = 24 WATTS @ 12 VOLTS (-1V, +5V)

In each of these cases the range of the device is 11 to 17 volts. Specifically, below 11 volts the device will cease to function properly (in some cases a camcorder or VTR will unthread or drop out of record below this voltage). Likewise, voltages above 17 volts may damage the equipment or, more likely, blow a fuse or breaker.

If you no longer have the technical manual, or Power entry has a single number such as:

VOLTAGE = 12 volts DC or POWER = 24 watts

You will have to determine the voltage range by other means. One method is a simple phone call to the equipment manufacturer. Talk to an engineer and give him your precise model number. Our experience has shown that in order to avoid confusion, the voltage range will be best determined by asking the following two questions:

1. “What is the lowest voltage I can supply to this device before quality or performance is adversely affected?”
2. “What is the highest voltage I can apply to this device without causing damage or blowing a fuse?”

Once the voltage range of your equipment is accurately determined, the next step is to establish which voltage battery has a range that falls totally within the range of your equipment. The voltage range of batteries typically used in the video industry is as follows:

"12 volt Nominal" Range = 10 - 14 volts
10 cells NiCd or NiMH

"13 or 13.2 volt Nominal" Range = 11 - 15 1/2 volts
11 cells NiCd or NiMH

"14 or 14.4 volt Nominal" Range = 12 - 17 volts
12 cells NiCd or NiMH or 4 cells Lithium ion

Matching the correct battery to your equipment is now straightforward. As an example, consider the typical technical manual entries above that listed the power range as 11 to 17 volts. In this case both the "13.2 volt" [11-15 1/2] and the "14.4 volt" [12-17] batteries have ranges totally within the equipment specification and are therefore fully compatible. In cases such as in this example where more than one battery is applicable, the best run time and reliability will always be achieved with the *higher* voltage battery. Note carefully that the range of the "12 volt" [10-14] battery extends below that of the equipment and is not compatible. In addition to the above, the following general facts may also prove helpful for proper voltage selection:

Voltage

1 - A "12 volt nominal" battery should never be used with modern video equipment. This is due to the fact that virtually every piece of professional video equipment designed in the last 10 years has a minimum voltage requirement of between 10.5 and 11.0 volts. Thus the 10 volt full discharge rating of a "12 volt nominal" battery is significantly below the minimum voltage requirement of all professional video equipment. (VTR batteries with cables such as BP-90 types and NP-1 types should be particularly avoided. See Technical Section)

2 - A "13.2 volt nominal" battery can operate virtually all professional video equipment. This is based on the fact that all video equipment specify a maximum voltage of 15.5 volts or higher, and a minimum voltage of 11 volts or lower (down to 10.5 volts). Thus the 11 to 15.5 volt range of a "13.2 volt nominal" battery falls totally within the operating range of virtually any video equipment which may be in use today. However, it should be noted that the performance and runtime of equipment can be unnecessarily limited by using a 13.2 volt battery which will not take advantage of the additional power and performance of a 14.4 volt battery.

3 - A "14.4 volt nominal" battery can be used with any equipment which specifies such a battery or has a maximum voltage rating of 17 volts or higher. A "14.4 volt nominal" battery will provide better performance and life relative to a comparable "13.2 volt" battery. This is true especially when selecting a NiMH battery or a small size battery whose smaller size cells have a higher internal resistance, thereby limiting its cold weather or high drain rate performance. Make sure your equipment can accommodate voltages as high as 17 volts before using a "14.4 volt" battery. As a rule, virtually all professional equipment now being manufactured are specified to deliver optimum performance with "14.4 volt" batteries.

Please feel free to contact Anton/Bauer Customer Support. An Anton/Bauer support technician can tell you which voltage and type battery will deliver optimum performance with your equipment.

VOLTAGE TECHNICAL SECTION

BATTERY VOLTAGE RANGE

While the 'nominal' voltage rating is technically meaningless, battery "range" limits are very significant. When a fully charged battery is first placed on a piece of equipment and power is turned on, the initial voltage may be as high as the upper range limit. Typically the voltage will drop quickly during the first few minutes of discharge, then continue to drop more slowly throughout the rest of the discharge cycle until the voltage reaches the lower range limit at which point the battery has released all its stored energy. The shape of this discharge curve and the rate at which the voltage drops is dependent on many factors including the power drain rate, battery size, age, temperature, and cell formulation. (See fig. #2) However, regardless of the shape in between, the lower limit remains the same and is called the 'End Of Discharge Voltage' or EODV by the cell manufacturers.

This EODV is the most critical voltage rating of a battery, and the *only* voltage specification stated by the cell manufacturer relative to capacity. This is the voltage down to which a battery must be taken in order to retrieve 100% of the available capacity. To put it another way, the cell manufacturer will guarantee full capacity *only* if the battery is discharged down to the EODV. Conversely, <u>you can not get all the energy out of the battery until it is discharged to this voltage.</u> Therefore, if the lower range limit of the battery (EODV) is below the lower operating voltage limit of the equipment, you will never get the full capacity or run time out of the battery.

Figure #1 clearly illustrates the problems of powering a modern piece of video equipment with a battery of improper voltage. In this example, the 10.0 volt End Of Discharge Voltage (EODV) rating of the "12 volt nominal" battery is significantly below the 11 volt minimum or "cut-off" voltage of the professional camcorder. Only a 13.2 or 14.4 camera battery fully conforms to the operating range of professional video equipment.

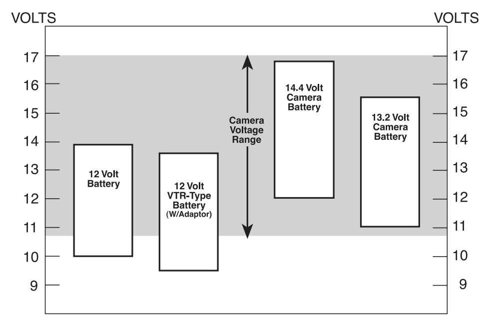


Figure 1

The discharge curve 'A', in figure 2, is typical of a "12 volt" NiCd battery in mid-life. Note that this battery is perfectly within specification and still delivers close to 100% of its rated capacity at its specified EODV of 10 volts. However, the camcorder can NEVER make use of all this power because as soon as the battery voltage falls below 11 volts, the camcorder ceases to operate. The battery appears to have 'lost' 25% of its capacity. In reality the rest of the energy is still in the battery, but the camcorder just can't get to it. This is called "unavailable capacity" and is totally due to a battery voltage mismatch with the equipment.

The resultant phenomena has become commonly *and inaccurately* known in NiCd chemistry as "memory" (see also "memory" in the Problem Appendix) is illustrated by curve 'B' where it is apparent that "memory" is actually a "voltage depression" phenomena. At the so-called "memory" point the voltage suddenly drops about 1.2 volts, where it is once again below the camcorder cut-off voltage. The camcorder stops and it appears that "memory" has caused a 50% loss of capacity. But if you look again, it is not really a loss of capacity. The battery will still deliver close to 100% capacity within the EODV voltage specification.

Curve ‘C’ represents a mid-life NiCd in cold weather. In this case the battery will run the camcorder for only 25% of its normal time. Again, there is nothing wrong with the battery. Curve ‘C’ is fully within the normal NiCd operating specifications yielding rated capacity at the EODV of 10 volts.

In all of these instances cameramen usually blame the apparent loss of capacity and run time on the battery ‘getting old’, that strange “memory thing”, or the cold weather. Considering these curves, it is easy to understand why “12 volt” batteries seem so unreliable. Depending on prevailing conditions you never know exactly how much run time you will get from a battery. In reality all three of these losses of capacity are due solely to the operator using the wrong voltage battery.

Curves ‘D’, ‘E’, and ‘F’ represent the discharge curves of a “14.4 volt” battery under the identical three conditions and with the identical camcorder. As if by magic the “getting old”, “memory”, and cold weather problems suddenly disappear. Why? Because the 12.0 volt EODV or full discharge voltage rating of the “14.4 volt” battery is properly *above* the 11 cut-off voltage of the camcorder. The curves of a “13.2 volt nominal” battery with an EODV of 11.0 volts would also deliver 100% capacity in all these cases.

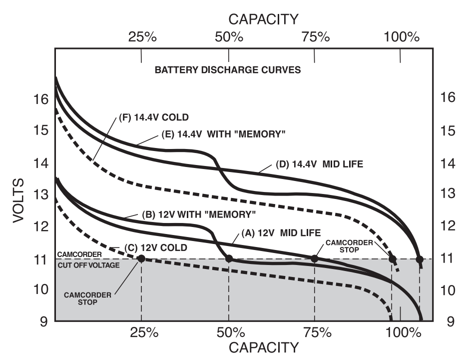


Figure 2

Small size batteries are constructed typically of smaller cells and have greater internal resistance which also results in a significant lowering of the voltage curve, especially under higher loads or cold operating temperatures. This also results in a significant loss of run time regardless of voltage level and a very severe loss of capacity in the above examples.

Because of the unique nature of lithium ion chemistry, batteries constructed with these cells can only be made into batteries in multiples of the generally nominal 3.6 volts of each cell (i.e. 3.6, 7.2, 10.8, 14.4, 18 volts, etc.). A 10.8 volt (3 cell) battery would be insufficient to operate a nominal 12 volt camera and an 18 volt (5 cell) battery would over-voltage the camera. Therefore, to power a professional 12 volt nominal cameras, lithium based chemistries can *only* be constructed in batteries employing four cells or 14.4 volts nominal. Considering the attention that lithium ion has received in the past few years, it only contributes to the voltage irony – lithium ion can only be used for a 12 volt nominal professional video camera in a 14.4 volt configuration.

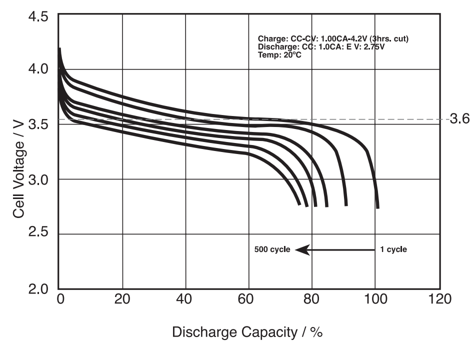
<u>However, it should *also* be apparent, then, that the loss of a single cell from a lithium ion battery will render the battery incapable of operating a camera.</u>

In the old days NiCd batteries were often rated at the “plateau voltage” of the battery - defined as the voltage at which the battery stays at for the longest time during discharge. Technically, the “operating voltage” of a battery is correctly defined at the midpoint of its discharge – that is if the battery runs for an hour then the voltage of the battery at the 30 minute mark is its “midpoint voltage”. For a NiCd (or NiMH battery for that matter) this is nominally 1.2V/cell, therefore giving rise to the 10-cell 12 volt battery, 11-cell 13 volt (13.2 V) and 12-cell 14 volt (14.4V) nomenclature. All this, of course, is at nominal temperatures, loads and service life. But generally speaking the battery will have an operating voltage of (1.2V X # of cells in series) for most of its service life.

Lithium ion is different from NiCd (and NiMH) in many characteristics. Operating voltage is just one of the differences. The voltage profile of li-ion changes over its life. All these changes are attributed to the increase in the internal resistance of the cell which increases over calendar time and over the number of charge/discharge cycles the battery experiences.

The voltage at which a lithium ion cell operates is approximately 3.6-3.7 volts midpoint voltage. Therefore, you *could* rate a 4 cell series battery from 14.4 to 14.8 – a difference of about 3%. BUT as the graph shows, the operating voltage, as well as the capacity of the battery, deteriorates significantly over the number of cycles - unlike nickel based chemistries where operating voltage remains relatively constant over the battery life.

Cycle Characteristics (Discharge Characteristics)



Now one needs to remember the calculations for capacity in watt hours:

WH = Operating voltage X capacity in ampere hours (Ah)

The “ratings game” used to be played by calling a battery 12 volt battery 4 Ah and equating it to a 4 Ah 14.4 volt battery suggesting that the “capacity” or runtime would be the same because the ampere hour “rating” was the same (see Capacity section below)

To clarify this Anton/Bauer pioneered the use of the more technically correct “watt hours” in video batteries, long before it became commonplace in the general battery world.

Enter lithium ion. Now, battery manufacturers can use the “nominal operating voltage” of a lithium ion cell to increase the advertised watt hours of their battery by 3% - without ever doing anything to the actual performance of the battery! Theoretically using the exact same construction of 2.1 Ah 18mm X 65mm cells from the same supplier, one battery manufacturer could call the battery 90 Wh and another could call their battery 94 Wh. Both would be technically correct but, assuming all other things are equal, the batteries will operate equipment for the same runtime. Moreover, the graph shows clearly that very quickly during the life of the battery that initial rating deteriorates rather dramatically.

Bringing us to our next characteristic – CAPACITY.

CAPACITY

There are many video professionals who have unwittingly crippled their field production capabilities by selecting the wrong capacity battery for the wrong reasons.

Video is very different from almost all other battery applications. A cameraman functions through his eyes and is comfortable only when he can ‘see’ through his camera. A film cameraman could look through his camera all day without a battery even being attached. But unlike a film camera, you can not ‘see’ through a video camera unless it is turned on and drawing full power. A video camera is always drawing power while the cameraman sets up his shot or waits for a politician to step outside of the capitol building. The power consumed by a video camera therefore has absolutely nothing to do with the number of video cassettes or disc space being consumed. A cameraman can often run through an entire battery before recording a single minute of tape or saving a single minute of video to disc. The critical consideration for video is the amount of time a battery can run a camera or camcorder.

The vital question when selecting a video battery is this: “How long should the equipment run between battery changes?”

The answer is a simple but emphatic: **at least 2 FULL HOURS.**

This two hour rule is the fundamental basis for selecting a battery for a professional video application: This is not an arbitrary or capricious guideline but rather a very serious specification which is based on extensive analysis of hundreds of professional video operations. It is also based on a purely logical objective - to minimize battery change disruptions.

Surveys of video professionals have indicated conclusively that more than one battery change disruption per morning/afternoon is unacceptable. One battery change interruption can be reasonably anticipated and is deemed manageable. However, two or more are perceived as random disruptions that seriously impair production efficiency and result in lost time and shots. The ultimate battery system is thus 4 batteries capable of operating for 2 hours and a four-position charger. Start the day with battery #1. Mid morning change to battery #2 if necessary. At lunch-break change to battery #3 (even if #2 is not fully depleted). Mid afternoon change to battery #4 when necessary. The result is a maximum of one interruption per morning/afternoon. But in order to assure this simple and efficient routine, the battery must be capable of running the equipment for a minimum of 2 hours.

A one-hour battery, by contrast, involves a very complex system of 10 batteries, 3 chargers, and the chaos of as many as 8 interruptions per day (see Technical Section). The classic reasons for making this mistake include the desire for a ‘small’ or ‘light weight’ battery. As the Technical Section explains, properly sized batteries can actually balance the camcorder *better* for less operator fatigue, and weigh less and cost less than the equivalent amount of smaller type batteries. Insufficient capacity can cripple a video operation. Start with the correct, efficient, and economical 2-hour battery for your application.

Determining the proper 2-hour battery for any application is simple. Capacity refers to the total power a fully charged battery can deliver and is properly measured in “watt hours” (not “ampere hours”, see Technical Section). To determine the proper capacity of a 2-hour battery for any application merely take the power rating of the camera or camcorder and multiply by 2.

2 x Camcorder Power (Watts) = Battery Capacity (Watt Hours)

As an example, assume your technical manual or the label on your camcorder states “Power Consumption = 26 watts”. The proper battery for that camcorder should have a minimum of 2 x 26 or 52 watt hours of capacity. After this calculation, select from those batteries with capacity ratings of 52 watt hours or greater. The following additional points should also be considered:

• In a true battery system there should be a variety of battery sizes and capacity from which to choose. This variety allows the professional to choose the appropriate battery to fit the shooting situation much the same way as he can choose lenses, filters and lighting. For example in the Anton/Bauer InterActive system, batteries from 45 to 160 watt hours can be used for different situations. For example, a small 50 watt hour battery can be used as an easy to carry spare, while the primary battery can be a 160 watt hour high capacity type to provide maximum runtime and performance. In this example, almost six hours of runtime (almost an entire working day) can be had from the 160 watt hour battery while the 50 watt hour pocket battery provides a “back-up” and minimizes the cost and number of larger batteries which need to be carried to a shoot.

• Most professionals use small ‘fill’ lights on their cameras to remove foreground shadows. Most new cameras and camcorders come from the manufacturer with provision to power such lights from the camera battery. These lights are popularly used for indoor available light situations (see Lighting Section). When using these lights, select a battery with slightly higher capacity.

• Battery capacity will fade somewhat with age. Cell manufacturers typically consider a battery to be within specification if it delivers 75% of rated capacity and define “end-of-life” as a capacity reduction of 50% from intial capacity. Therefore, do not cheat on this ‘2 x power’ formula as the mid-life capacity of the battery may decrease by 20% while a more severe loss of capacity may occur later. Nickel based chemistries will tend to exhibit a “plateau of capacity” for most of its life losing capacity rapidly over the last 10% of its life until it is unserviceable. Lithium ion batteries exhibit a linear life profile and lose capacity over their life a little bit each time it is used.

• The capacity rating of a battery is a “theoretical optimum” number. It is not like the gallon capacity of a gas tank in your car. Choose your charging system very carefully (See Charging Section). The actual capacity of a battery is totally dependent on the recharging process. Depending on the type of charger and prevailing conditions, a so-called ‘charged’ battery may fail to provide even 1/3 of its ‘rated’ power. You can not think ‘battery capacity’ without thinking ‘charger’.

CAPACITY TECHNICAL SECTION

The topic of capacity is technically more complex than the simple rating number would suggest. Like voltage, the capacity rating is "nominal" and in practice the actual amount of energy a particular battery can deliver to a camcorder can vary over a wide range depending on a multitude of parameters and conditions. This section will provide a better understanding of the most significant elements that can affect the available capacity of a battery and the run time of your camcorder.

Watt hours or Ampere hours? - The most classic cause of confusion involves the units used to rate battery capacity. While cell manufacturers rate *individual* cells in "ampere hours", the proper unit for the measurement of energy in a group of cells (the definition of a battery), is the "watt hour". This is quite evident since watts are the unit of power and hours are the unit of time. The outdated practice of rating a battery in 'ampere hours' is both incorrect and misleading.

As an example, assume a "12 volt" battery and a "14.4 volt" battery are both rated at 5 ampere hours and are to be used with a device that draws 24 watts. Given that both batteries have the same "capacity" of 5 ampere hours, one would conclude that both batteries will run the device for an identical length of time. But this is not true. The "nominal" watt hour capacity rating for each of these batteries is calculated as follows:

"12 volt / 5 AH" Battery -
Nominal Capacity = 12 (volts) x 5 (AH) = 60 Watt Hours

"14.4 volt / 5 AH" Battery –
Nominal Capacity = 14.4 (volts) x 5 (AH) = 72 Watt Hours

The nominal run time is calculated by dividing this capacity rating by the power of the equipment:

60 Watt Hours ÷ 24 watts = 2 1/2 Hours Run Time with "12 volt" Battery

72 Watt Hours ÷ 24 watts = 3 Hours Run Time with "14.4 volt" Battery

Thus the "14.4 volt" battery will provide a minimum of 20% greater run time compared to a "12 volt" battery with the identical 'amp hour' rating – without the problems associated with 12 volt batteries. It should now be evident why the ampere hour rating is misleading.

Always compare and select batteries using 'Watt Hour' ratings. From the above example it also should be clear that you can determine the nominal run time of any battery by simply dividing the Watt Hour Rating of the battery by the power draw in watts of the equipment.

Testing Capacity - Many technicians make the common mistake of testing battery capacity by discharging through a load resister or light bulb and using the number of minutes to fully discharge the battery as an indication of capacity. Unfortunately this method produces highly erroneous results. An example will best demonstrate the fallacy of using discharge time as an indication of capacity:

Two NiCd or NiMH batteries are to be tested for capacity, one is a ten cell '12 volt' while the other is a twelve cell '14.4 volt'. Both fully charged batteries are discharged on a load resister or light bulb with a resistance of 3 ohms. The '12 volt' battery runs a full hour (60 min) while the '14.4 volt' runs only 55 minutes before reaching their respective EODVs. Most technicians would conclude that the '14.4 volt' battery had almost 10% less capacity than the '12 volt' battery. In reality this test proves the '14.4 volt' battery actually has 32% more capacity than the '12 volt' battery.

Using the basic formula I=V/R (current equals voltage divided by resistance), the '12 volt' battery was being discharged at 4 amps by the 3 ohm resister while the '14.4 volt' battery was being discharged at the higher rate of 4.8 amps by the same 3 ohm resister. Taking the broad liberty of using the 'nominal voltage' rating as an 'average voltage', the capacity of the '12 volt' battery would be calculated by multiplying '12 volts' by the 4 amps discharge current times the one hour duration:

'12 volt' battery capacity = 12.0 x 4.0 x [60/60] = 48 watt hours
Similarly:
'14.4 volt battery capacity = 14.4 x 4.8 x [55/60] = 63.4 watt hours

Thus while the discharge test seemed to indicate that the '14.4 volt' battery had less capacity, in reality it had greater than 30% more capacity and would run a camcorder more than 30% longer than the '12 volt' battery. This timed discharge test is equally misleading for lighting applications since the higher voltage battery not only raises the wattage rating of a given bulb, but also increases the lumens/watts efficiency of the bulb. Thus, for a given fixed level of illumination, the '14.4 volt' battery would also provide longer illumination time than the '12 volt' battery.

Simply remember, battery discharge data must be rendered into Watt Hour Capacity otherwise it is totally irrelevant and misleading.

Rated Capacity - The capacity rating of a battery is extremely dependent on the rate of power drain. In addition to the aforementioned EODV, every cell manufacturer always includes a current specification with the capacity rating such as "5 ampere hours (or 5000 milli – ampere hours) @ 5 ampere current drain". This specific example is called the "C" rate or "One-Hour" (discharge or charge) rate. In other words, the battery will deliver "5 amps for one hour". Because of internal resistance and other factors, the effective capacity will be less at greater current drains. Conversely the effective capacity will be greater for lower current drains. In the above example, this same cell may be rated: "5.5 ampere hours @ 1 ampere current drain" which is the "C/5" or "five-hour rate" capacity. Likewise the "C/10" or " ten-hour" rating may read: "5.8 ampere hours @ 1/2 amp current drain". Cell manufacturers will typically use one of these three standard rates to specify capacity. Virtually all lithium ion and small NiMH cells are rated at the C/5 rate. Since this discharge rate makes the cell "appear" to have higher capacity.

The "Numbers Ratings Game" - Note from the above that the cell appears to magically gain capacity as you go from the 'one-hour' to the 'five-hour' and then to the 'ten-hour' rating method. Some battery manufacturers use this 'magic' to make their batteries sound like they have more capacity. The rating of cells by cell manufacturers today, especially the newer NiMH and lithium ion chemistries, tends to have little bearing on the accurate appropriate rating of batteries for professional video. These chemistries, have been designed for and used primarily in relatively low power requirements. Therefore, the cell manufacturers specify the capacity of these chemistries at the C/5 rate.

However, when these chemistries are applied to the much higher power requirements of video equipment, the cell rating cannot be used to rate the batteries accurately and honestly. Because the cells are typically smaller in size and the construction of these chemistries exhibit high internal resistance, as the current draw is increased the available capacity of the battery is dramatically reduced. By way of example, "4/3A" size NiMH cell rated at 4000mAh (4Ah) discharged at the C/5 rate (800mA) will deliver only about 3500 mAh at a C-rate (4A) discharge. Limited by an internal resistance typically *10 times* that of NiMH and NiCd, this phenomena ratings game is widely seen played in lithium ion cells and and batteries.

Theoretically and ethically, a battery should be rated using the method that most closely approximates the power drain and run time of the intended application. For all video applications this is most definitely the 'one-hour' or "C" rate method. which is used by most professional video battery manufacturers. Unfortunately not every company offering video batteries uses rates their batteries to the application. They use the rating that the cell manufacturer uses to rate a single *cell* for applications drawing 1/5 of the power of a typical professional video camcorder.

In addition to this numbers game, the relationship between current drain and available capacity is very relevant when comparing batteries of different sizes even if they are properly rated. The term 'effective capacity' refers to this variation of capacity under different current loads.

Effective Capacity - Contrary to popular belief and simple logic, two 50-watt hour batteries will deliver less run time than one 100-watt hour battery. This is due to "effective capacity" which derates the capacity of a battery based on increased power drain. In essence, a 25-watt camcorder represents a 'light' load to a 100-watt hour battery but appears twice as large to a small 50-watt hour battery. As a result, the 50-watt hour battery may actually deliver only 40 or 50 watt hours while the 100-watt hour battery will provide a full 100 watt hours with the same load. Thus it may take ten 50-watt hour batteries with up to 9 change disruptions to equal the run time of four 50-watt hour batteries with only 2 interruptions. In addition, the 10 smaller batteries will weigh more than the 4 larger batteries. And don't forget "charge position". Ten smaller batteries will require 3 four-position chargers instead of one. In most cases the longest runtime per battery system is less expensive to purchase and far more economical over time.

Camera/Camcorder Balance - The critical mistake of selecting a battery with insufficient capacity can almost always be traced to the misguided penchant for a 'lighter weight' battery. In reality, most video professionals agree that good balance is far more critical than a minor difference in overall weight.

With wide angle and widescreen lenses becoming more sophisticated and heavier, and camcorders becoming more compact, the overall package is becoming front-heavy on the cameraman's shoulder. This front biased weight places a fatiguing strain on the operator's right arm and back. In almost all cases the proper 2-hour battery at the rear will perfectly balance and stabilize the camera, eliminating back and arm fatigue while operating the camera for longer periods. *A camera with a "heavier" battery, that counters the lens weight, can be more easily managed, be steadier and feel more comfortable than an unbalanced camera equipped with a "lighter" battery.*

The irony here is that many cameramen create all the insufficient capacity problems outlined above thinking that they are getting some kind of weight benefit. In reality they *trade away current carrying capability, runtime and camera comfort and stability* and in their effort often increase the number of batteries, and therefore the weight, they carry to a shoot.

Capacity and Voltage - Do not forget the lesson of figure #2 in the Voltage Technical Section. Using a battery of insufficient voltage can reduce available capacity up to 80%, especially in cold weather conditions. Access to 100% of the available capacity can be assured *only* if the EODV of the battery is *above* the cut-off voltage of the camera/camcorder.

Capacity and package size – simply put there is a big difference in the 65 watt hours of a large NiCd battery and the 60 watt hours of a small lithium ion pack. Because of the construction of the cells and the differences in the chemistries, for a given load the lithium ion battery, constructed of the smaller cells could be working 10 times as hard as the NiCd pack. While the smaller pack has a tremendous advantage in power per unit of volume or weight, the larger pack is capable of powering a much larger load – like a camcorder, on-camera light, monitor and wireless receivers. So instead of requiring separate batteries for these devices – the battery constructed of the larger cells can handle these loads easily. You wouldn't specify a motorcycle engine for a race car – smaller engines work harder and have shorter lives. Careful consideration of the operating capabilities of the battery *with the equipment you want to power the way you want to use it* is key. Size matters, but performance and long service life are just as key.

Capacity and Charging - When you get to the Charging Technical Section you will learn that despite everything that has been said here, the charger/battery relationship ultimately determines whether the battery will run the camcorder for two hours or two minutes.

BATTERY CONSTRUCTION

It is quite ironic that in this era of "high tech", many battery problems, failures, and hazards are still the result of something so mundane as poor 'packaging' techniques. A rechargeable cell is actually a very fragile device that can be damaged or destroyed by physical forces typically encountered every day. In the case of lithium ion chemistry, the requisite circuitry necessary to allow the safe operation of this technology, must be included on a printed circuit board in each battery. Lacking the properly designed electronics, protective casings and professional construction techniques, a battery has no hope of surviving in the real world of professional ENG/EFP. Moreover, improper construction can create a very real and serious risk (See Safety Hazards Section).

To assure dependable operation and preclude failures and hazards caused by poor construction techniques, choose a battery based on the following design guidelines:

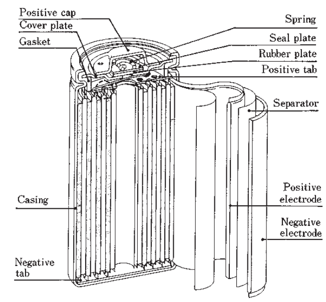
1 - The battery should have a very durable case of high impact injection molded material. The cells inside should be isolated from the case at points of critical stress such as corners. Badly packaged batteries offer no protection to the cells or critical safety circuits and will transmit any impact directly to these vital components causing internal cell damage or dangerous failure of safety circuitry.

2 - Look for solid, unitized construction which distributes and absorbs impact like a crash helmet. Avoid batteries that are constructed of two halves that are screwed together. Screws can create stress concentrations that will crack under impact and also prevent impact energy from being distributed evenly over the entire battery.

3 - Electrical contacts must be low-resistance and preferably gold plated multi-point contact types. Insertion of the battery into the charger or camcorder should result in significant 'wiping action' to maintain a clean and reliable connection. The contacts must also be recessed significantly to preclude short circuits should the battery accidentally come into contact with a small metal object. Avoid cables and connectors which will exhibit high resistance thereby lowerings the output voltage and significantly reducing run time. In addition, these cable type connectors are very prone to damage and failure in the field.

The importance of a rugged and well designed case has recently gained additional significance. Some of the latest high capacity cell and new chemistries achieve greater energy capability by utilizing thinner cell casings and an internal construction which is more fragile. Without adequate protection, fragile cell constructions often cause more problems than they solve in the real rigors of a video operation.

CONSTRUCTION TECHNICAL SECTION



This figure illustrates the basic interior construction of a rechargeable cell. The basic elements include one positive and one negative plate that are kept apart by two extremely thin separators. These plates and separators are wound together jelly-roll fashion and 'stuffed' into a thin walled metal canister. The negative plate is welded to the bottom of the canister. After the proper amount of liquid electrolyte has been added, the positive plate is welded to a top-cap that is then used to seal the top of the canister. The insulating ring between the cap and canister also helps create an 'airtight' seal. While the cell is designed to operate as a 'sealed system', a safety vent in the cap will discharge the excessive pressure that could result from improper charging or discharging practices. The key word in this paragraph is "thin"; thin separators, thin plates, and thin-walled canister.

Lithium ion cells have a significant variation in construction. These cells, because of their potentially volatile nature if abused, have a safety vent which is designed to electrically disconnect the cell in the event of overpressure. This overpressure can be caused by charger failure, physical abuse or cell imbalance in the battery. Designed to be only a "last ditch" or "failsafe" safety mechanism*, the safety vent in a lithium ion cell is not designed to be resealable.* If battery and charger are operating properly, the safety vents of the cells in a battery should never operate. If the vent does open*, it is designed to simultaneously disable the cell and thereby the battery pack*. Because the electrolyte in lithium ion chemistry is an organic material it is highly flammable. The cell (and its safety vent), if operating properly, is theoretically designed not to allow the escape of this material.

Internal Short Circuits - The canister of any rechargeable cylindrical cell offers very little protection to the internal components. Firstly, it is so thin you can easily crush the canister between your thumb and forefinger like a miniature beer can. Secondly, the internal plates and separator assembly are practically press fit into the canister so that even the slightest deformation of the canister will cause a corresponding distortion and stress to the plates and separator. The separator is the only thing keeping the positive and negative plates from touching and it is so thin that you can see through it like tissue paper. Thinning out plates and separators is the primary method for putting more active material and thereby more energy into the same size cell. These two facts account for one of the most plaguing battery problems: the high impedance internal short circuit.

Accelerated Self Discharge and Imbalanced Batteries - When a battery is tossed onto a shelf or accidentally knocked against another object, a cell case can be slightly dented, creating a permanent internal pressure point. At this pressure point the two plates are being squeezed together and eventually the separator begins to break down allowing a small leak of current to pass from the positive plate to the negative. This phenomenon is sometimes referred to as 'accelerated self-discharge'. Depending on the severity of the 'short', a cell can totally discharge itself in a few days or even a few hours. This condition causes several serious and sometimes perplexing problems.

In the case of lithium ion cells, a damaged cell will render the entire battery useless – there is literally no room for error. Because each cell has a nominal voltage of 3.6 volts, a 14.4 volt pack is constructed of 4 cells. Eliminating one damaged cell reduces the voltage of the pack to 10.8 volts, which is below the operating voltage of a camcorder. Thus the battery is permanently and irrevocably “dead”.

Because NiMH and NiCd batteries are constructed of 12 cells of 1.2 volts each (to make a 14.4 volt pack) the battery can still operate a camcorder with one or two cells damaged. While these cells may be totally depleted, the remaining cells may actually be fully charged. However, because of its reduced performance and the inability of conventional chargers to address this conditions, batteries exhibiting this condition will often be discarded (as an offering to the “memory” gods) despite the fact that the battery is still fully operational with the equipment.

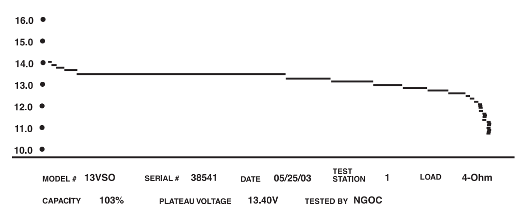
BATTERY DESIGN FEATURES

The voltage, capacity, and case construction of a battery are critical elements that can be easily qualified. However, there are many other aspects and features of a battery design that can have a profound effect on the efficiency and reliability of an ENG/EFP operation. When selecting a battery system, the following additional points must be considered:

Cell Type and Quality - There are now many different cell types, chemistries and formulations available from a multitude of cell manufacturers around the world. *Relatively few of these manufacturers produce cells with the quality and performance features which meet the requirements of professional video*. Within this small group of premium cells there are several different formulations that have specific performance benefits and trade-offs. Factors such as run-time, overall life, economy, and charger compatibility must be considered. The Cell Formulation Technical Section below covers some of the more basic aspects of cell selection.

Internal Battery Construction - While the integrity of the overall battery case is the paramount construction feature, the quality of the internal assembly is also quite important. All cells should be strap welded to eliminate high resistance connections. Cell insulating sleeves should be heavy-duty fiber type instead of thin PVC plastic. PVC plastic insulation can crack and split due to temperature variation, causing shorting between cells and potential fire hazards. The design should incorporate printed circuit boards and molded-in wire channels which eliminates wire flexing, connection fatigue, and pinched wires that can cause short circuits. An analysis of assembly techniques and components combined with plain common sense can often indicate which batteries will survive in the field and which are failures or hazards waiting to happen.

Quality Controls - Research has shown that an analysis of the first few cycles of a battery can reveal potential problems that would eventually prove disruptive in the field. We believe the computerized 100% full discharge testing performed on every Anton/Bauer professional battery is an exemplary form of quality assurance. This computer print-out, which is shipped with each battery, indicates capacity, voltage plateau, and includes a complete voltage discharge curve which is the most effective indication of overall cell matching and performance.



"Universal" Vs. InterActive Batteries - All batteries can be classified into two basic categories: (1) so-called "universal" replacement type batteries, and (2) Batteries that are an integral part of an InterActive™ battery/charger system.

The "universal" type usually includes just two electrical contacts and a fixed rate fast charger output. The InterActive battery is part of a battery/charger system that relies on precise battery data to facilitate accurate and dependable charging. The battery must therefore have a network of sensors and circuits in order to monitor the necessary parameters and provide the data required by the interactive charger. The battery must also include communication contacts in addition to the two power output contacts. As explained in the charging section, only an InterActive battery/charger system should be considered for professional video and film applications.

Digital Battery - The most advanced InterActive battery is the Anton/Bauer Digital battery that includes a microprocessor in addition to the other sensors and circuits. These on board electronics provide the highest level of charge accuracy and convenience while facilitating a new type of automatic battery management and maintenance system.

The Digital battery pioneered a unique feature that has become a standard feature for today's cameraman. The microprocessor in the battery includes a "fuel computer" program that monitors electrical current both into and out of the battery and accurately computes the state of charge, remaining capacity and remaining runtime at all times. This accurate computation of available capacity and remaining runtime of the equipment is displayed in a LCD on the battery. The cameraman knows at a glance the remaining capacity or runtime available from the battery. In addition to this LCD in the battery, all professional video camera/camcorder manufacturers include a 'remaining battery capacity indicator' or 'fuel gauge' in the viewfinder that couples instantly to a special InterActive contact on all Anton/Bauer Digital Batteries. This InterActive viewfinder display can be a 'bar graph' or digital 'percent remaining' number.

Cameramen have been mislead for years by the unreliability of the meaningless 'low battery warnings' which merely measure battery voltage. This fuel gauge feature, now included as a standard, without modification to the camera, on virtually all camcorders (and many other types of equipment) from all manufacturers.

Battery Mounting - The following points should be considered when selecting a battery and mounting system:
1 - A quick-release mount is preferable to a battery that slides into a box or compartment. The box concept restricts the equipment to a specific size battery while a quick-release mount allows the user to use any of a variety of battery types and sizes to match a particular assignment. Furthermore the quick-release mount allows the equipment to be made much smaller for transporting by merely removing the battery.

2 - Do not use batteries that have a cable mounted connector. The high resistance of the small connector can cause voltage reduction problems while the wire and its mating with both the battery and connector have consistently been identified as the most frequent cause of battery failure. In addition, these connectors often have no latch or mechanism and frequently become disconnected inadvertently during operation and charging.

3 - Make sure the power contacts are rated for a minimum of 10 amps and are self cleaning 'wiping action' type connectors where a male plug slides into a corresponding female socket. Avoid 'touch' type contacts that are not self cleaning. Also avoid contacts that are riveted. Lastly avoid the use of any connector that creates a "point"contact. The larger the surface contact between male and female connection the more reliable the connection will be under load.

4 - The battery mount on the camera should include a power socket designed specifically to power a camera mounted light or other accessory such as wireless receivers. Camera mounted 'fill' lights powered from the camera battery have become necessities for high quality location video. This power connection should be independently fused, and capable of handling up to 85 watt loads. In this way, a wide variety of lighting requirements can be addressed while protecting the camera even if a problem develops with the light. Avoid lighting outlets on the battery itself. First, these connections require the light or accessory to be unplugged every time the battery is changed. Second, because a failure of this connection could disable the battery leaving the operator with no power for the camera.

CELL FORMULATION

Nickel Cadmium (NiCd)

The continued development of higher energy NiCd formulations, improved manufacturing techniques keeps this technology in the mainstream of portable power, especially in high power applications such as power tools and professional video. These improvements have been dramatic in recent years with capacities improving as much as 50% or more over the past 5 years. Design requirements driven by power tools and by the alternative transportation markets have led to a renewed interest by cell manufacturers in NiCd cell design and manufacturing methods. This renewed development stems from the failure of other rechargeable chemistries, such as NiMH, lithium ion and lead acid to approach the broad range of sizes, high current capability, low resistance and service life of NiCd.

With the advent of worldwide recycling and reclamation programs, any early environmental concerns regarding the disposal of nickel cadmium cells have been addressed decisively by the battery industry. Today all types of batteries – lithium ion, nickel metal hydride, NiCd nickel cadmiuim and sealed lead acid are handled in recycling programs around the world similar to those recycling glass or cardboard. (for more information see www.rbrc.org for information on the Rechargeable Battery Rrecycling Corporation, which Anton/Bauer is a member.)

Charge times for NiCd batteries of about 1 hour can be up to 3 times faster than either NiMH or lithium ion, making NiCd indispensable to a fast paced professional. In the many applications of greater than 40 watt power requirements (such as a camcorder and on-camera light), NiCd remains the only rechargeable technology which optimizes the factors of cost, reliability, runtime and service life.

The service life of NiCd batteries is unmatched by any other cell chemistry in video applications. In typical operation, especially in professional use, NiCd chemistry offers as much as *three times the cycle life* of any other chemistry.

Within the NiCd family there exists the widest variety of cell sizes and formulation. Since the differences within NiCd batteries can be significant to their operating characteristics, the following discussion offers an explanation of the three types generally encountered in professional video batteries.

1 - “Sintered/Sintered” - This is the classic premium NiCd cell which has been employed by most professional video battery manufacturers for more than a decade. This designation refers to the fact that both the positive and negative plates have been impregnated with active material using a sintering (baking under pressure) process. This type of construction has earned a well deserved reputation for ruggedness, long life, and consistent performance under a wide range of conditions. Developments in sintered/sintered technology have resulted in improved capacity while retaining the other desirable attributes of this type cell which include heavy duty construction and low internal resistance. This type cell is still the choice for applications stressing reliability, high power drain, and long life under extreme conditions.

2 - “Pressed” or “Pasted” - While this type cell also utilizes a sintered positive plate, the active material is pressed onto the negative plate. (Japanese cell manufacturers use the term “pasted negative” while Americans refer to this type cell as a “pressed negative”). This type cell is typically considered to be of inferior quality relative to a sintered/sintered. Though it exhibits slightly greater initial capacity for its size, the pressed negative cell never-the-less remains unpopular for professional video applications. This was due to several serious drawbacks which included an inability to be effectively fast charged, shorter cycle life (especially when fast charged), higher internal impedance, and greater susceptibility to internal damage and shorts.

3 - “High Porosity” - This type cell is based on a very high porosity plate construction that is sometimes called “sponge metal” or “foamed positive”. Which exposes significantly more plate material to the electrolyte and thus the battery appears to have the plate area of a larger cell. Such technology theoretically holds the promise of greater power density for certain applications. However, this cell construction exhibits all the aforementioned characteristics of a pressed negative type cell and the associated caveats of susceptibility to mechanical shock, high drain limitation, and shorter cycle life expressed above apply equally to this type cell.

Nickel Metal Hydride

Advancements in NiMH have improved this technology to offer very high watt hours per unit of volume. The weight of a nickel metal hydride cell is about the same as a NiCd and the same number of cells are required to make a battery of a particular voltage. NiMH cells have the same voltage as their NiCd cousins with the ability to store more energy due primarily to the highly porous metal hydride electrode.

In practical application, no conventional NiCd charger can handle the stricter charge controls required by NiMH technology (see CHARGING SECTION below). C-rate charging with TCO, $-\Delta V$, and/or timed cutoffs are not acceptable methods to terminate charge. NiMH are not “drop-in replacements” for NiCd cells in any battery application. NiMH cells have a lower tolerance for high rate charge (excessive heat buildup lowers charge acceptance) and overcharge (degrades performance and cycle life). In fact, the cutoff methods employed for NiCd products by conventional chargers will not protect NiMH cells from damage (for example the $-\Delta V$ specification for safe charge cutoff is <u>twice</u> as precise as with NiCd). The only precision cutoff methodology for NiMH is a dT/Dt (change in temperature over a specified period of time). This cutoff methodology has been implemented in the computer industry since the early 90’s (such as the type developed by Anton/Bauer for Apple computer based on the video InterActive™ Digital battery) and sophisticated processing of temperature information supplied by the battery. Every Anton/Bauer InterActive charger possesses the ability to perform the dT/Dt calculations necessary to handle NiMH effectively and safely.

The operating characteristics of NiMH cells have been dramatically improved in recent years. Early NiMH cells were restricted by limited low temperature performance as well as high temperature cycle-life limitations. However recent improvements in NiMH chemistry, as well as the high voltage design of Anton/Bauer HyTRON batteries have virtually eliminated these concerns. HyTRON 50 batteries were the only power source for an expedition from Death Valley to the top of Mount Whitney experiencing operation temperatures ranging from around 100°F (38°C) to 15°F (-10°C). The cells used in the HyTRON 120 battery were specifically designed for high current applications such as electric bicycles and power tools.

Unlike any other chemistry new to professional video, HyTRON batteries do not require the purchase of a new charger to take advantage of the battery's performance. Any Anton/Bauer InterActive charger with full communication capability can be upgraded with a new software chip to safely and reliably charge HyTRON.

Lithium Ion

Of all rechargeable chemistries, theoretically, lithium ion offers the future promise of smaller lighter batteries to match up with small low power equipment. For over 40 years cell manufacturers have been attempting to harness the energy potential of exotic metals, such as lithium, into a reliable and safe rechargeable technology. Every early attempt was disastrous, leading to catastrophic and costly failures of batteries and equipment. Lithium ion chemistry, which does not use lithium metal in its pure form, has been more successful in recent years in small two-cell batteries for low power equipment. Unfortunately, several lithium ion product recalls have perpetuated safety concerns and design considerations.

The major advantage of lithium based cell chemistry is the voltage of the cell. Instead of being a nominal 1.2 volts per cell, lithium based chemistry has a nominal 3.6 volts. This *voltage* advantage (the *capacity* of any particular size lithium ion cell is typically about the same as a nickel based chemistry) allows a 14.4 volt nominal battery to be made with only four cells in series instead of 12 cells for the nickel based chemistries. However, since the lithium ion cells are currently only manufactured in the small sizes designed for cell phones and computers, to obtain the same capacity in a similar volume package, the cells must be paralleled to obtain requisite capacity. Therefore, to obtain capacities equivalent to other chemistries as many as 12 cells (or more depending on the size of the cells) must be used. The resultant volume and capacity of the lithium ion battery is equivalent to batteries made with the other chemistries, while its weight will be about 20% less.

The single major disadvantage of this chemistry is made obvious by the absolute requirement for on-board "protection" electronics to prevent overcharge (which results in catastrophic failure) or over-discharge (which renders the battery useless). These electronics must monitor each and every cell in the battery to prevent any over charge or discharge of any cell. This should be a relatively simple process for a single cell (3.6 volt battery) but gets increasingly more complex and subject to the tolerances of the cells and the electronics. This is especially the case as the cells are paralleled to obtain higher capacities.

Lithium ion chemistry is being employed, primarily in small size (AAA or small rectangular sizes) 2 cell configurations in the cellular industry and in the computer industries, where primary considerations are weight and size. Moreover, the devices they are designed to power (computers and telephones) have additional battery monitoring programs which can improve performance and reliability.

Lithium ion cells can retain their charge for a somewhat longer time than other technologies. However, lithium ion batteries stored for any time *irreversibly lose capacity* (see discussion of self discharge and battery storage below).

Another drawback to lithium ion technology as a professional battery is its inability to address high rate discharge. The internal resistance of lithium ion cells used in professional video batteries is up to 10 times that of similar cell sizes in NiCd and NiMH. In fact, the battery itself must be fitted with electronics to limit the amount of current that can be drawn from the battery. While this is of little consequence in a “closed system” like a cell phone where the battery is matched exclusively to one device for its lifetime, in a video operation a battery can – and will - be used on a variety of equipment

When trying to operate a camera and on-camera light for example, the protection circuitry (required to protect the cells from over-current) can often shut the battery down as the increased load pulls the battery voltage down even momentarily. Some cameras attempt to get around this by limiting the current which can be drawn from its accessory connector for the light. A voltage regulator in the camera limits the current draw of the light rendering it virtually useless for high wattage bulbs, like those used for daylight fill. Since the camcorder and light configuration is the most popular and economical operating arrangement in professional video, this limitation is significant for this chemistry.

Unquestionably lithium ion differs dramatically from any other rechargeable technology due to the nature of its electrolyte. Much of the technical discussion in the battery industry regarding lithium ion has to do with some well founded concerns of reliability and safety. The electrolyte (the liquid medium which allows the transfer of electrons between the positive to the negative plates) and the volatility of lithium metal (which can be formed under certain abuse situations) are the characteristics which a great deal of the R&D efforts by the cell manufacturers are seeking to improve. Currently, most lithium ion cells in all applications and all those employed in professional video batteries use an organic electrolyte which is highly flammable. Unlike other chemistries, which uses an aqueous (water based) potassium hydroxide electrolyte, a lithium ion cell itself can support a fire.

The battery industry is actively pursuing development efforts to address this issue – such as polymer based electrolytye. However this technology has even less current carrying capability and as yet is not capable of producing a professional video battery to meet the demands of today’s video equipment.

Since its first introduction in the early 1990’s there have been numerous lithium ion battery catastrophic failure “events” primarily in the notebook computer and cell phone markets. In every market where lithium ion appears, including professional video, there have been associated product recalls as a result of serious safety concerns.

When choosing a lithium ion battery, make certain that the battery is constructed with the requisite safeguards and is supplied by a reputable and experienced manufacturer. Avoid look alike batteries that may not have the same safeguards in design and manufacture as the original manufacturer’s products. Never charge a lithium ion battery on any charger other than the charger on which the battery was designed to be used.

Lead Acid or Gel Cells

This cell chemistry has no viable application to professional or consumer video today. The only allure of lead acid/gel cell batteries was their initial low cost. In reality these cells were more expensive than NiCd due to a significantly shorter cycle life and unreliable performance. With a high internal impedance, these type cells also exhibited significantly reduced 'effective capacity' in professional video applications. Relative to a comparable NiCd battery, lead acid/gel cell types are bigger, heavier, more costly, have less than 1/4 the cycle life and are irreparably damaged if left in the discharged state for extended periods.

Silver Zinc

These type cells have been popular in limited circles since the advent of ENG/EFP. At that time, silver zinc had a power density 3 times that of NiCd and several television networks opted to build an ENG operation around this technology. Cameramen loved the 'shoot-all-day-on-one-battery' aspect which eliminated battery interruptions and the need to carry extra batteries. However, silver zinc is extremely unforgiving due to operating limitations and its list of maintenance procedures.

While it remains widely used in military applications, silver zinc is no longer considered a viable alternative for professional video.

CHARGING

Once a professional battery of the correct voltage and capacity for a particular application has been selected, *the success or failure of your video operation will depend almost entirely on the charging system*. Poor and erratic performance is primarily due to a basic characteristic of rechargeable batteries known as "charge acceptance". Simply stated, a battery actually rejects or accepts any or all the current from a charger depending on a multitude of prevailing conditions. Contrary to the outdated popular concept, a battery is not like the fuel tank in your car that merely has to be 'filled' with a specific quantity of fuel. A battery is more organic and can not be 'filled' with charge current any more than a flower can be 'filled' with water. In order to achieve optimum capacity a battery must be 'fed' charge current in a precise manner according to a multitude of parameters and conditions. All conventional chargers ignore these factors and merely deliver a fixed and steady flow of current, reducing battery performance to a mere game of chance. It is not uncommon for a charger to indicate that a battery has been given a full charge and is 'ready' to use when in fact the battery has 'accepted' less than half the charge current and thus contains less than half its potential capacity.

It is now acknowledged that the charging process must consider all the parameters and conditions that affect charge acceptance in order to properly charge a battery and assure optimum performance. This is exactly the basis of the latest innovation in battery technology: InterActive battery/charger systems. The key to this technology is designing the battery and charger together as a complete system. During charging, the battery and charger "talk" to each other. The battery is designed with a network of electronic sensors that monitor vital charging parameters while a program module contains critical data such as cell formulation, capacity, and voltage. All this data is fed to the charger microprocessor which then creates the optimum charge regime for that battery under the actual prevailing conditions. In essence the battery is controlling the charge process by telling the charger who it is and how it wants to be fed today. This technology brings rechargeable batteries from the dark ages into the space ages with consistent and dependable high performance while eliminating the fire and hydrogen gas explosion hazards that have always existed with conventional chargers.

This is the only rule of charging you need to know: *select an InterActive battery/charger system for dependable high performance and safe trouble free operation.* With the development and introduction of this highly reliable system technology, it would be a travesty to base a professional video operation on anything else. (The Technical Section covers the specific benefits and technical features of this system as well as the problems of conventional charging.)

NiMH and lithium ion batteries can *not* be charged on conventional NiCd chargers, or more to the point, these batteries can be destroyed and create a hazard to the operator if such is attempted. An InterActive charger includes its programming on a replaceable chip within the charger. As each cell improvement or new cell technology is introduced, the corresponding charge regimes may be programmed into an updated chip that is simply inserted into the charger in place of the old one. The updated charger could will then identify and properly charge the new type batteries as well as all the older types simultaneously. With a system that anticipates inevitable technology changes, a gradual and economical transition to advanced new chemistries is possible now and in the future.

CHARGING TECHNICAL SECTION

It is the charging system, or more precisely the battery/charger interaction, that will ultimately make or break a portable video operation. Assuming a professionally constructed battery of correct voltage and capacity has been selected for an application, all remaining problems of poor or erratic performance can always be traced to improper charging practices or a charger with insufficient control and safety circuits.

Charging different chemistries used in professional video requires the employment of radically different charging routines. Each chemistry – NiMH, NiCd, lithium ion – require different methodologies based on the characteristics of the chemistry. The three characteristics common to all cell chemistries which indicate charge completion are temperature, voltage and internal cell pressure. Each of these factors are equally important. *As a cell nears full charge, the voltage of the cell, its temperature and pressure all will rise. The art in charging a cell is to obtain the most charge without the increase in these parameters exceeding safe limits specified by the design of the cell*. Exceeding the limits of any of these factors, depending on the chemistry, can lead to unreliability, shortened service life or in some cases catastrophic failure of the cell, including explosion and/or fire.

Unfortunately, the best indicator of charge completion, internal cell pressure, is virtually impossible to monitor. The rise in gas pressure internal to the cell cannot be monitored economically, especially in a multi-cell pack – as it would require the equivalent of pressure gauges on every cell. It is, however, the internal pressure of the cell which, when exceeded, can cause the destruction of the cell. Since the buildup of pressure cannot be effectively monitored, the precise control and monitoring of the other two characteristics is paramount in proper charger design.

All cells used in professional video are vented. That is, they possess as part of their mechanical designs, safety mechanisms – in the form of vents - to release gas pressure built up during any charging which exceeds the parameters of the cell design.

These safety mechanisms are *vents* which allow the buildup of gases created during overcharge to be released from the cell. In the case of NiMH and NiCd cells the vents are resealable. This means that the nickel based technologies not only can withstand some degree of overcharge, but if the internal pressure limits are exceeded, the cell can expel small amounts of any excess gas. The expelling of the gas will typically carry with it some of the liquid electrolyte in the cell. This electrolyte is a relatively benign material in nickel based rechargeable cells (typically potassium hydroxide in a water based solution). The loss of too much electrolyte due to venting will ultimately prohibit the ability of the cell to generate an electro-chemical reaction, thereby rendering it useless.

In the case of lithium ion chemistry, the vent is designed to be a *one time device*. That is, <u>since the lithium ion cell is incapable of absorbing the effects of any overcharge, the vent is designed to electrically disconnect the cell</u> – much in the same way as a fuse breaks an electrical circuit. The cells are designed in this fashion to prevent the escape of any liquid electrolyte. Since the electrolyte used in lithium ion cells is an organic material (another liquid organic material, by way of reference is gasoline) with an extremely low flash point (or temperature at which the material will ignite), the release of any electrolyte could be catastrophic to the battery and to personnel. It is for this reason that a lithium ion battery requires the use of electronic circuits in the battery design to monitor other battery parameters to prevent any build up of gases from overcharge.

The next best indicator of full charge is temperature. The temperature of a cell will typically rise as it reaches end-of-charge due to the cell's increased internal resistance and its corresponding inability to absorb the energy being delivered by the charger. The two ways which temperature can be monitored is by an absolute change (TCO) and a relative change (ΔTCO). Both NiMH and NiCd cells can be most effectively charged using a temperature method. By monitoring the temperature of the cell, the full charge state can be determined <u>before</u> any build up of gasses occurs. This method is the most effective when dealing with a multi-cell pack – as all professional video batteries are constructed.

Lastly, the most conventional and basic method of approximating the full charge of a cell is by monitoring its voltage. Charging to a particular voltage (absolute voltage) or charging to a calculated inflection point (-ΔV or peak voltage) are typical methods of using voltage to determine full charge. Unfortunately, since professional video batteries are made up of from 4 (lithium ion) to 10-12 (NiMH, NiCd) cells, the accurate monitoring of <u>each individual cell</u> in a battery pack is almost impossible (see voltage cutoff discussion below). The charger, however, is only capable of "seeing" the *combined* voltage of the entire series pack. Because the voltage change of any given cell can be disguised by an inverse voltage differential of another cell or group of cells in a series pack, protecting the individual cell requires the use of precision monitoring circuits connected to each cell. Using *only* a voltage cutoff can lead to the overcharging of one or more cells in a series pack, one factor causing so-called "memory" in nickel based chemistries.

In the case of lithium ion, the required <u>individual</u> cell voltage monitoring <u>must</u> be done *within the battery pack itself*. The charger is able to determine the voltage of only the entire pack. These on board battery electronics should signal to the charger the attainment of the end-of-charge voltage of any individual cell before any dangerous overcharge can occur. These essential electronics are built into the battery and must be protected from the same shock, vibration and environmental conditions to which the battery is subjected in field use.

NiCd and NiMH batteries are typically charged with a *constant current* methodology, meaning that the charger will deliver a constant amount of current to the battery regardless of its voltage. In charging this way the current delivered to the battery can also be measured and a fail-safe time termination can also be employed.

Lithium ion chemistry must be charged with a constant voltage architecture (constant current may be applied early to expedite the charge process but a constant voltage methodology is required as the cell becomes mostly charged). This means that the voltage applied to the cell(s) is constant and the current applied will be reduced as the voltage of the cell(s) increases. This charging method is similar to the method used to charge lead acid batteries. Only the voltage of the cell(s) can be used to determine full charge and must be done so with extreme precision, as lithium ion chemistry is incapable of absorbing any overcharge safely as discussed previously.

The following discussions address the most commonly recognized methods of charging, as well as the mis-application of these methods which cause premature battery failures.

SLOW CHARGING

Every NiCd cell used in the video industry has an inherent ability to accept a certain amount of overcharge current indefinitely. NiMH has a limited tolerance and lithium ion has an absolute zero tolerance for overcharge. In the case of NiCd, the tolerance to overcharge is largely due to the typical cell construction with a negative plate that has slightly more area than the positive plate. During charging, virtually all the charge energy is being stored in the cell by converting the chemical elements of the internal plate compounds. The cell is essentially fully charged when all the positive plate material has been converted. If the charge current continues past this point, it can not be absorbed by chemical conversion and instead produces oxygen gas at the anode. This oxygen is contained in the cell where it eventually finds its way to the unused portion of the larger negative plate where it is absorbed. In the process of absorbing oxygen, heat is created and thus the overcharge current is essentially dissipated as heat. The cell is designed to dissipate a certain amount of overcharge current in this manner indefinitely with no immediate adverse affects. If the overcharge current were greater than this 'C/10' rate, the cell would begin to produce oxygen at a rate much faster than it can absorb. The internal pressure would rise dramatically until the safety vent opened spewing forth gas and electrolyte. This ability to absorb oxygen has its definite limit which is usually at a current that is one tenth the ampere hour rating of the cell (C/10 rate). Thus a 5 amp hour NiCd cell can typically absorb up to 0.5 amps or 500 ma of overcharge current continuously with no immediate adverse effects.

This continuous ability to dissipate an overcharge current of up to 'C/10' is the precise basis and definition of a "slow" or "overnight" charger. The term "trickle charge" is also used to describe charge rates of 'C/10' or slightly less. Such chargers are incredibly simple and in many cases consist of little more than a transformer and a diode in a small black box. The 'C/10' constant current will typically charge the appropriate battery in 16 to 20 hours and when the battery is fully charged there is allegedly no problem as the battery will happily dissipate the continuing charge current indefinitely. At first glance the 'slow' or 'overnight' charger seems foolproof, economical, safe, and dependable.

Contrary to its deceptively simple concept, the slow charger is an outdated concept and should always be avoided for professional video applications for several important reasons:

1 - TIME - Slow charging is too slow for professional applications. The 16-20 hours necessary for a complete slow charge is totally unacceptable in a professional operation.

2 - CELL FORMULATIONS - Modern cell chemistries have an optimum charge acceptance at the one hour or 'C' or 1It rate. When charged at the slow rate, they can exhibit reduced capacity with each charge cycle.

3 - HEAT AGING - The vital plate separators and cap seal of a cell deteriorate with age. As a matter of fact, separator failure and the resulting benign internal short circuit is one of the more common forms of battery end-of-life failure. Elevated temperatures will accelerate the deterioration of any organic material and batteries are no exception.

Unfortunately, the slow charging process dissipates the continuing excess charge current as heat.

4 - RESTRICTED APPLICATION - Because of its inherent simplicity and constant current output, a slow charger must be dedicated to one specific voltage and capacity battery. A slow charger can be totally ineffective if connected to a battery with a greater rated capacity or slightly higher voltage than that for which it was designed.

A slow charger should never be connected to a lithium ion or NiMH battery.

"FAST" CHARGING

Virtually all professional chargers are high rate chargers capable of delivering a fully charged battery within 8 hours and often within one hour. "Fast" charging is used to define a one-hour-to-cutoff charger, however with the advent of longer requisite charge times of NiMH and lithium ion, "fast" chargers are typically categorized as any charger that will deliver a complete charge routine on a battery in under 8 hours.

CHARGE TERMINATION

In order to comprehend the criticality of any 'charge termination' procedure, consider that the popular one hour fast charge routine for a NiCd battery uses a charge current that is ten times greater than the 'C/10' rate. Thus when the cell reaches full charge it will begin to produce oxygen gas at a rate *10 times greater* than its maximum absorption capability resulting in a rapid (and potentially catastrophic) build-up of pressure and temperature.

The charge termination or 'cut-off' is the most critical element of any battery charger, and it is the inability of unsophisticated chargers to dependably execute this function that is responsible for the poor performance, poor service life and sometimes hazardous malfunctions of today's video batteries of all chemistries.

Generally, all modern cell formulations 'like' to be fast charged (at rates approaching the "C" or one hour rate) and will deliver optimum performance and charge acceptance when fed a fast charge rate under proper conditions. However, this situation is reminiscent of the old tale about the man who fell off the roof of a 20 story building and was not injured from the fall. However, the sudden stop at the pavement killed him. Likewise, the problem is not the high current charge rate, but rather the failure to reliably terminate this high rate of current once the cell is fully charged.

Accurate and dependable recognition of the full charge condition of a battery under all conditions is extremely difficult. As discussed previously, the only cut-off method for a lithium ion cell is the attainment of an absolute and precise voltage, which is monitored in the battery and must be communicated to the charger. NiMH and NiCd cells can be charged using one or more of the following termination techniques:

VOLTAGE CUT-OFF [VCO] - This is the most popular method of fast charge termination for NiCd cells. It is the only method that can be used with conventional two contact (+ and - only) batteries. As can be seen from figure 3, the voltage of a NiCd cell steadily rises during the charge process. Upon reaching full charge, the cell begins to generate and reabsorb oxygen gas as previously described which causes the voltage to drop. In its best form, a VCO charger uses a microprocessor circuit to monitor the charge voltage and terminate the fast charge current when this reduction in voltage is sensed. Such chargers are also called -ΔV ("minus delta vee") types because of this process. In addition, the microprocessor can also monitor and respond to other relevant characteristics of the charge voltage, which is referred to as 'voltage algorithms'. All these methods that rely on the charge voltage for fast charge termination are generically VCO type chargers.

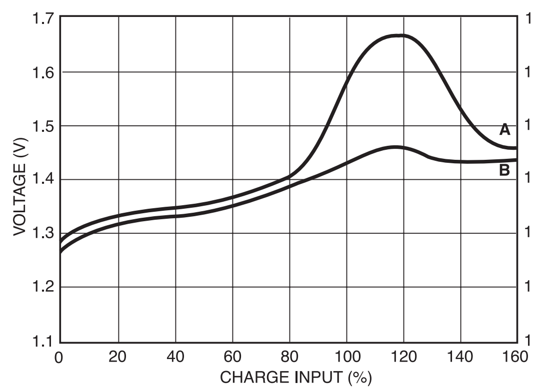


Figure 3

Looking at fig 3, the voltage profile, and in particular its -ΔV aspect, appears to be a reliable and effective basis for determining the full charge of a NiCd or NiMH battery. Actually, if video batteries consisted of one cell and were always charged under controlled conditions, this method would work just fine. Unfortunately, every cell manufacturer states that the VCO method, and the -ΔV type in particular, becomes progressively problematical and unreliable as the number of cells in the battery increases. All professional video batteries (except lithium ion) consist of 10 to 12 cells in series and thus the problems associated with this type charger should have been anticipated and expected. The problems with this method are primarily related to temperature and cell imbalances.

The pronounced rise and then dip in voltage (-ΔV) of figure 3 curve A is based on an optimized charge rate at room temperature. If the charge rate or the temperature deviates from these optimum values, the magnitude of the -ΔV dip may be reduced dramatically (figure 3 curve B) causing it to become unrecognizable to the charger termination circuit. Thus termination will not be properly executed which will overcharge the battery and create a fire hazard. This problem often occurs with warm or hot batteries but is particularly acute with cold batteries.

The -ΔV charger can rarely recognize a cold battery, resulting in one of two very undesirable conditions. The initial high impedance of a cold battery may create an immediate rise and drop in voltage when charging begins which prematurely triggers the "Full Charge" cut-off. This is why a battery from one of these chargers can sometimes have a "READY" indication and yet remain uncharged. More typically, the charger does not receive a false trigger and delivers the full fast charge current to the cold battery as if it were at room temperature. Cell manufacturers clearly warn that this is the most dangerous thing you can do to a NiCd battery. A cold (40°F or less) NiCd can not accept the full fast charge current and will generate *hydrogen* gas under these circumstances. When such a battery is removed from the charger or placed on a camcorder a spark can ignite the hydrogen gas causing the battery to explode. (See *Safety Section*)

The -ΔV charger can not recognize or cope with cell imbalances either. The cells used in premium batteries are usually matched for capacity before assembly. At Anton/Bauer every professional battery is 100% computer tested for performance and cell balance with the computer print-out shipped with each battery. Nevertheless, the 10 or more cells within a video battery will eventually develop slight differences in capacity due to a multiplicity of factors including unequal rates of self discharge. As Murphy would predict, the probability that 10 to 12 cells will reach full charge at the same instant is virtually nil. As one cell is increasing in voltage toward the end of charge, another cell is decreasing in voltage, etc., etc., etc. Because the charger can only read the sum voltage of all these cells in series, the cells with rising voltages cancel out the reduction in voltage of those cells that have reached full charge. As a result the charger 'sees' a relatively flat voltage curve and misses the charge termination point. This is why the cell manufacturers are wary of using the -ΔV technique in such multi-cell applications. Based on this same syndrome, these type chargers can not cope with batteries that have "memory" or imbalances caused by high impedance shorts. Such batteries will either be destroyed, damaged, or result in a partial charge.
(See *Memory* in the Problem Appendix)

In addition to the hazards, it is clear from the forgoing why batteries charged on these type chargers have been notoriously unreliable. Depending on temperature, cell matching, and many other factors, the battery may receive a reasonably full charge one day and a mere fraction of a charge on the next.

TEMPERATURE CUT-OFF [TCO] - Upon reaching full charge, the continued charge current will begin to create heat inside the cell due to the oxygen absorption process. The subsequent rise in temperature in cells designed for this cut-off method is a very definite and reliable indication that the fully charged condition has been achieved. When properly monitored and analyzed this rise in temperature can be a very effective and dependable basis for a fast charge termination system. A TCO system must include the appropriate temperature sensors in the battery and an additional connection between battery and charger for the transmission of temperature data.

In addition to being an effective means of fast charge termination, temperature information can be extremely vital to many other charger functions. The relevance and accuracy of battery voltage data during charging is significantly improved when coupled with cell temperature information. Likewise, the charge acceptance factor that greatly influences battery performance is also very temperature dependent. The microprocessor of an InterActive battery/charger system uses the critical cell temperature along with other vital data to optimize performance and life as well as eliminate the safety hazards of cold temperature charging.

DELTA TEMPERATURE CUT-OFF [DELTA TCO (dt/Dt)] - The most advanced temperature type cutoff method is employed in the Anton/Bauer Digital InterActive battery. The Digital battery contains special temperature sensors which convey real time temperature information to the charger's microprocessor allowing the charger to analyze the rate of temperature change of the cells in the battery pack. This analysis is then used to determine a precise fast charge cut-off point which is more accurate than either VCO or standard TCO methods.
This cut-off method is essential for safe charging of NiMH (Nickel metal hydride) cells.
A temperature compensated ΔT/Δt is a proprietary standard feature of all Anton/Bauer Digital

InterActive batteries and chargers eliminating many of the variables to this type of cutoff that temperature extremes can introduce.

DIGITAL OR FULL BATTERY CUT-OFF [FUL] - Another feature only available with the Anton/Bauer Digital InterActive battery and chargers is the FUL cutoff. Due to the InterActive technology, an Anton/Bauer InterActive battery can communicate it's own state of charge to the microprocessor in the charger. Therefore, when a battery reading 100% in it's display is placed on the charger, no charge current is needed to bring that battery to one of the aforementioned cutoff methods. The battery merely tells the charger to enter the proprietary Lifesaver mode to keep it at the 100% charged level without adding any additional heat to the battery, therefore prolonging the life of the cells.

COMPUTATION (or CAPACITY) CUT-OFF [CCO] - The CCO or Computation method of fast charge termination is a very dependable complement to either the TCO or the VCO systems. This pre-determined charge profile is established prior to the start of the charge cycle by the charger's microprocessor during the battery evaluation phase. By recognizing the battery's cell formulation, temperature, rated capacity and number of cells, the InterActive charger's microprocessor will select a fail-safe maximum charge profile from its database. The charger continuously monitors the charging process against the battery's maximum charge profile and will terminate charge automatically if this profile is exceeded.

An explanation of these five termination methods usually prompts the question: "Which one is best"? And the answer begins with "none of them". Each method has its strong points and a specific range over which it is effective, however no one of them are totally safe and dependable over the full range of conditions that are normally encountered in the professional film and video industries.

Voltage Cut Off systems, including microprocessor 'voltage algorithm' types, are reasonably effective under ideal conditions but can be extremely unreliable and hazardous if the battery is cold or imbalanced. The TCO techniques as exemplified by the Anton/Bauer ACS and Digital InterActive battery systems are extremely effective and are the only safe methods to charge cold or imbalanced batteries. DT/dt is the only safe and reliable method of terminating charge in a NiMH battery. The CCO method is a safe and reliable 'back-up' system and is effective under a wide range of conditions, but because it is a 'computation' method it lacks the accuracy requisite for use as a primary cut-off method.

The final answer to the question of which charge termination system is best is: "all of them together operating simultaneously and independently".

While all conventional chargers employ only one charge termination method, Anton/Bauer InterActive Microprocessor chargers when used with Anton/Bauer InterActive batteries include all five types of termination systems which operate at all times. Every Anton/Bauerbattery includes a complex network of sensors and logic circuits that provide the charger microprocessor with the critical temperature and cell data to facilitate an accurate TCO, Delta TCO, temperature correlated VCO, FUL or CCO cut-off. The charger monitors all these systems simultaneously and will accurately terminate the fast charge when any one of these systems recognizes the full charge state. This fail-safe multi-redundant technique utilizes the strengths of all these methods while it precludes the inherent weaknesses of any one system. This is the only system that is safe and effective over the entire range of possible conditions.

CHARGE ACCEPTANCE

As mentioned above, a battery is not a “fuel tank” but rather an organic system that will efficiently store energy by an internal chemical transformation when fed electric current (charge rate) in a *precise manner and under specific conditions.* When these specified charge rates and conditions are not met, the internal chemical transformations do not proceed in their normal manner. Under certain conditions the normal chemical transformation will cease altogether and all the charge current will be diverted into secondary reactions that result in no energy being stored at all. These secondary reactions include the formation of explosive gas as well as destructive heat.

It is ludicrous to expect reliability from a charger that just throws out a fixed electric current without any regard to the critical conditions and parameters that affect the chemical transformation. Yet virtually all conventional chargers do just that. Charging a battery with one of these conventional non-interactive chargers is nothing more than a game of chance.

Among the major factors affecting ‘charge acceptance’ (the ability of a battery to store the energy delivered by the charger) are temperature, cell formulation, and the rated capacity (size) of the cell. The dire consequence of a charger ignoring these factors can be deduced by analyzing just one element of the complex charge routine: average fast charge current. Consider the following facts taken directly from cell manufacturers’ specifications:

1 - For a given cell, the fast charge rate must be adjusted by a factor of over 1,000 % according to prevailing temperature in order to assure optimum charge acceptance and remove the danger of explosion.

2 - Given a particular size cell, the fast charge rate must be adjusted by a factor of over 500% according to chemical formulation and internal structure.

3 - Fast charge current for a particular cell formulation and temperature is directly proportional to cell size or rated capacity. Since professional video batteries utilize cells typically in the range of 2 AH to 8 AH, this represents a corresponding variation in charge current of another 400%.

From these three specifications it should be clear that based upon the size, formulation, and temperature of the cells, the safe and optimum charge current would have to be adjustable over a range of 200 to 1 or 2,000 %. This means that a conventional charger with a single fixed fast charge rate can be delivering up to *200 times* too much or too little current to a battery according to the safety and performance specifications of the cell manufacturer.

INTERACTIVE CHARGE TECHNOLOGY

The basis of InterActive charge technology is very logical and simple: each battery actually contributes to its own charge process according to its size, chemical formulation, temperature and all the other parameters and conditions that affect charge acceptance in order to optimize performance, safety, and overall life. The battery of an InterActive battery/charger system features a network of sensors and logic circuits that can generate all the vital data necessary to create an optimized charge routine. Through a special communication link, the InterActive charger responds to this data by delivering a charge profile that perfectly matches the cell manufacturer's specifications under the prevailing conditions. All elements of chance and the risk of uncharged batteries, fire, and explosion are removed.

In addition to dependable performance, safety, and prolonged life, this InterActive technology is also the basis for a new concept in battery system management. Batteries have always represented an inordinately large percentage of video maintenance time. By comparison, modern cameras and recorders require little attention and a stock of fresh video tape is easy to maintain. Only the battery is an unknown consumable that can cause unpredictable disruptions when they fail. How do you keep track of the age, recent performance, and use pattern of a battery in order to identify a potential problem before it becomes a failure in the field?

The high level of data available from the battery and microprocessor charger of an InterActive system can facilitate a sophisticated and automatic maintenance program. InterActive chargers built-in diagnostic units can automatically test batteries for capacity, voltage profile, and all other major parameters. Through LCD or attached printer, these sophisticated units can automatically identify battery anomalies before they cause disruption in the field.

BATTERY LIFE

The overall life expectancy of a rechargeable battery is greatly influenced by a myriad of factors which have been frequently responsible for reducing the life of a battery to less than 30% of its theoretical maximum. There are many video professionals that accept the fact that a battery appears dead after only 6 months or a year. Most of the factors affecting life have been addressed throughout this handbook under the associated headings. The following is a compendium of the major factors influencing battery life with recommendations for optimizing each.

<u>Heat</u>- Batteries should not be exposed to elevated temperatures. Heat greatly accelerates the aging process and can reduce battery life by more than 80%. In the case of lithium ion (and to a lesser extent NiMH) the effect of storage in elevated temperatures can worsen a relatively new phenomena of "unrecoverable storage capacity". This characteristic of the so-called "new" chemistries defines a condition in which the storage of these batteries, whether charged or discharged, leads to a loss of capacity which can never be regained. Unlike NiCd cells, which have very good storage or shelf life characteristics, the chemical construction of these batteries will degrade much faster over time. This degradation is accelerated under high temperature (40°C and greater) storage conditions. The "use it or lose it" properties of NiMH and lithium ion chemistries are exacerbated by any long term (30 days or more) storage, particularly at elevated temperatures.

Whenever possible keep batteries at room temperatures. In extremely hot climates, keep batteries out of direct sunlight where possible and return batteries to an air conditioned environment at the earliest practical opportunity. Avoid leaving batteries for extended periods in an enclosed van or the trunk of a car. A simple styrofoam cooler can help insulate batteries in extreme temperatures. Common sense can easily predict the many other elevated temperature situations that should be avoided. In short don't keep your batteries anywhere you would not store your tapes or your camera.

During storage for periods greater than a few weeks, batteries should be wrapped in a sealed plastic bag and placed in a refrigerator. Before being returned to service, the batteries should be allowed to achieve room temperature before being removed from the plastic bag. Once at room temperature, the batteries should be charged on an InterActive charger in order to equalize and compensate any minor self- discharge. Do not use a conventional charger which has no means for addressing imbalances. Especially in the case of NiMH and lithium ion chemistry, it may take several charge and discharge cycles following storage for the battery to return to its optimum capacity.

A charger can often cause the worst elevated temperature environment for the battery. Improper charge termination and a trickle charge can create extremely high temperatures which are maintained indefinitely while the battery is on the charger. An InterActive battery/charger system with accurate temperature sensors and the Lifesaver maintenance mode will prevent this common form of heat damage. If you are <u>not</u> using an InterActive battery/charger system, feel the temperature of a battery that has been on the your charger for about 20 hours or longer. If it is warm or hot to the touch, it is being prematurely aged by a trickle charge. (If it is at room temperature, it probably is receiving no maintenance charge and will thus self-discharge probably limit the performance of the battery despite the charger's "full" indication).

Charging - The charging process has a great influence on battery life. For maximum life every battery requires a specific charge profile for a given set of conditions. Any deviation from this optimum profile will have an adverse affect on battery life. As an example, two identical batteries, charged with different chargers, provided similar performance during the operational life of the batteries. However one battery delivered twice the number of cycles and twice the length of service of the other due the differences in the charge routines. In extreme cases, an improper charge regime can destroy a battery and create a hazard.
As previously explained, only an InterActive battery/charger system has the ability to identify and create the proper charge profile required for maximum life and performance.

The following guidelines will help prevent extensive life reduction.

a) Do not connect a battery to a charger unless both the battery and charger are from the same manufacturer. While a charger may appear to be correctly charging a battery, an improper charge rate or charge termination profile can adversely affect life in addition to impairing performance and creating a hazard. The use of different cell chemistries, often disguised by a familiar form factor and connection format, offers a tremendous chance for serious incompatibility and dangerous operation.

b) Avoid so-called "equivalent" replacement batteries or "re-built" batteries. Remember both the battery and the charger are responsible for performance. While such replacements or re-builds may 'look' identical to the original, the internal cells typically differ from the originals for which the charge regime was optimized. Unfortunately such life reducing incompatibility does not show up until the battery dies in a fraction of the expected time. This and other internal differences that reduce performance can as well as create a serious safety risk.

c) Do not use slow chargers as a primary means of recharging and avoid chargers that utilize a continuous trickle charge as a "maintenance" charge.

d) Maintain adequate air circulation space between batteries and around charger. Make sure the charger is on a hard surface and not on a rug or carpet.

e) Do not routinely use so-called 'dischargers' or 'conditioners' before recharging. (See 'Discharge-Before-Charge Section' in Problem Appendix)

Discharge Rates - The life of a battery can be significantly affected by the relationship between the size of the battery (rated capacity and cell size) and the rate of discharge.
For a given size and type battery, higher discharge currents will reduce overall life expectancy while lower discharge currents will enhance battery life. (This is primarily due to internal impedance and heat).

As this rule applies to video, the life expectancy of a battery will not be adversely affected by a power consumption that is approximately half that of the capacity of the battery in watt-hours. For example, a 25 watt camcorder will have very little impact on the life of a battery rated at 50 watt-hours or greater. However, as the power consumption approximates the capacity of the battery or greater, life expectancy will be diminished. As a comparison, 50 watt-hour batteries powering the aforementioned 25 watt camcorder may provide months of additional service after 25 watt-hour batteries in the same application have expired. Thus for maximum life, as well as the previously stated practical reasons, select a battery with twice the rated capacity of the power consumption.

This rule is somewhat complicated by the introduction of batteries constructed of small cells primarily designed for low rate discharge (like computers and cell phones). While these batteries may boast of capacities equal to those of larger batteries, the small cell size used in these batteries is rated for delivering its capacity at much lower discharge rates. Due to the internal impedance of these small cells, a discharge of 25 watts is often up to 3 times greater than the discharge rate used to determine their rating (see The "Rating Game" discussed previously).

Over Discharge - Discharge current must never be allowed to continue after the battery has reached the EODV or end of discharge voltage. Running a camcorder or especially a light while the battery voltage is below the EODV can create a condition known as reverse polarity which will irreparably damage the battery and reduce its overall life. (See Problem Appendix). Therefore, never leave a battery powered piece of equipment unattended while it is running. Moreover, always change to a fresh battery as soon as a 'low voltage warning' appears or the InterActive battery indication signals for a battery change.

Physical Shock - Transporting batteries unrestrained in a large case or loosely in the trunk of a car can create extremely high impact forces that will create conditions that will adversely affect both life and performance. In addition to selecting a ruggedly designed battery, always transport batteries in a fitted case or compartment. Maximum life will be attained when batteries are not dropped or excessively submitted to severe impacts.

Cell Type - Life expectancy is also a function of cell type. Certain cell formulations and constructions will trade-off as much as two thirds of comparable cycle life for other attributes such as power density or cost. This is especially true of newer cell chemistries. Before selecting a battery, make sure you consider its life expectancy relative to its other specifications and to those of other similar batteries.

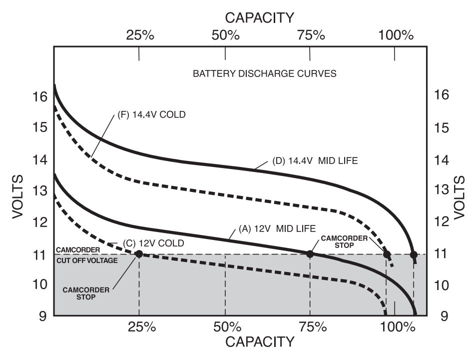
SAFETY HAZARDS

Assuming proper battery and charger design, the operation and charging of batteries is extremely safe. Conversely, life threatening explosions and serious fires can result from failure to follow the explicit safety guidelines presented by the cell manufacturers. Unfortunately, the great majority of battery and charger manufacturers have responded to these critical safety hazards by merely printing small warning disclaimers on their equipment and in the instruction manual rather than designing safe equipment that would prevent these hazards from occurring. If these warnings and danger labels are not adhered to in the manufacture and use of any type of battery, serious damage and injury may result. All users of rechargeable batteries should therefore be acutely aware of the following dangers.

Cold Temperature Charging

The fast charging of a cold battery is one of the most dangerous hazards associated batteries and can result in a violent explosion. By way of example, when a NiCd battery is fast charged at temperatures below +41˚ F (+5˚C), the internal charging reaction can not proceed normally and a significant portion of the charge current can be diverted into producing highly explosive hydrogen gas within the cell. Cell manufacturers emphatically state, that to avoid the risk of hydrogen gas explosion, the high rate charge current must be reduced or terminated to the battery when the temperature of the battery is below +5˚C. Despite this danger, every conventional charger now being manufactured can not properly identify a potentially hazardous cold battery. These chargers can deliver to cold batteries charge currents typically 10 times greater than the safety limits set by the cell manufacturer.

Every cell manufacturer, for every chemistry, provides a specification for an acceptable charging temperature range. Because cold temperatures increase internal resistance and slow chemical reactions, cold temperature charging of any chemistry battery can be a potential hazard. When the charger manufacturer warns: *"Charge batteries that are between +5˚C and +40˚C only"* - he is not kidding.



Anton/Bauer believes the risks of cold temperature charging are too great to be relegated merely to a warning label. Therefore every Anton/Bauer professional battery has a unique cold temperature protection circuit. There is never any risk of danger if a battery that is below the safe fast charging temperature is placed on the charger. The cold temperature safety sensor in the battery mates with the charger safety programs which then automatically control the charge rates to remain well within the safe limits specified by the cell manufacturers. Thus, when using an Anton/Bauer system, the threat of cold temperature hydrogen explosions are virtually eliminated.

Again it must be stressed, except when using an InterActive battery with its cold temperature protection circuit on a complimentary InterActive charger, a cold battery should always be allowed to reach room temperature before being placed on a charger.

Fire Hazards

Unfortunately conventional batteries and chargers have been identified as the source of potential hazards for years. After one such incident that almost resulted in tragedy, a major television network mandated that cameramen not charge batteries in their hotel room. An understanding of the conditions that can cause these disasters and the use of properly designed batteries and chargers can virtually eliminate any possibility of a fire or smoke hazard. The cause of all fire and smoke incidents can be basically grouped into these categories:

1 - Failure to terminate charge - The vast majority of incidents can be traced to a charger that has failed to recognize that a battery has reached full charge. As explained in the Charger Technical Section, one of the most critical functions of the charger is to recognize the moment that a battery reaches full charge in order to terminate the high fast charge current. Failure to terminate the fast charge current on time can have catastrophic ramifications. In the case of nickel based chemistries, the continuing high current, is typically *10 times greater* than a fully charged cell can tolerate, and will produces inordinate amounts of heat. In the case of lithium ion chemistry, the failure of the charger to recognize the termination point forces the reliance on the backup safety circuitry in the battery. If that circuitry is damaged or is improperly designed then the battery can go into a thermal run-away condition, bursting the cell and igniting its electrolyte. If this sounds dramatic, for anyone who has not seen it happen – it is.

A safely designed battery should always include a thermal fuse in the power circuit which will disconnect the battery from the charger or any other external device in the event that dangerous internal temperatures are detected.

2 - Slow Charging - A slow charger is a very simple device that delivers an appropriate and safe rate of charge current only when it is connected to the specific model battery for which it was designed. If a slow charger is connected to any other battery, particularly one with fewer cells, less capacity, or a different chemistry, the battery could generate an abnormal amount of heat that may be sufficient to cause a hazard.

3 – "Universal chargers" -– There are many chargers that can – or claim to – charge batteries having the same looking case and connection as the original manufacturer. This can easily mislead operators into believing that two chargers with very different characteristics and capabilities are interchangeable. *Only charge batteries with the charger designed for it by the battery manufacturer.* And only use batteries designed by the manufacturer of the charger. There is no such thing as a "universal" charger in professional video. Every reputable manufacturer has a different construction to its batteries and charger which cannot be anticipated by another reputable manufacturer.

4 – Incompatible chemistry - Unless you have an InterActive charger, do not use batteries of different chemistries (see Cell Formulation Section) on the same charger. Even though the batteries may fit, chargers that use only + and – are usually incapable of identifying the type of battery attached to them. In many cases some new chemistry batteries are constructed to "fool" the charger into thinking that a battery is the same conventional NiCd battery for which an older charger was originally designed. Moreover a charger may have the ability to recognize the proper battery but not to reject an improperly designed or incompatible battery.

Only an InterActive charger is capable of both identifying a battery consistent with its programming and rejecting a battery for which the charger was not designed.

5 - Blocking air circulation - For safety as well as reasons of battery performance and life, batteries should always be charged in a position that maximizes free air circulation. Specifically, batteries should not be grouped close together or left in a bag or case during charging. Chargers should be operated on a counter, tabletop or bare floor – never on a carpet. Likewise, other objects should never be placed on top of charging batteries or the charger.

6- Physical Shock and External Short Circuits - Any professional battery can become a hazard by releasing incredibly high rates of current if the battery is inadvertently short circuited. A short circuit can instantly transform internal wires and connecting straps into red hot elements. This has been known to happen when a battery is accidentally dropped. In such cases the impact causes an internal collision between two or more cells sufficient to tear the thin insulating sleeves thus creating a direct short. A pinched wire can create the same disaster.

It has been shown that this type hazard can be effectively eliminated through preventative design measures. Heavy duty fiber type cell insulating sleeves should be used as they can survive repeated impacts that would cause plastic sleeves to fail. While more rugged insulating sleeves are highly desirable, the best approach is to prevent major impacts from reaching the cells or creating movement between the cells. As discussed in the Battery Construction Section, a high impact thermoplastic unitized case will perform this function. It is also important that all power conducting wires and straps are channeled in a manner to prevent chafing or pinching under impact.

An external short circuit can create the same fire hazard as an internal short, however this is more easily avoided. The external power contacts should be recessed and the battery should include an externally replaceable and/or internal resetable fuse in the power circuit.

(Anton/Bauer InterActive battery/charger systems comply with all the safety recommendations suggested in this Safety Hazard Section).

WARNING: Based upon reported incidents, so-called "equivalent" replacement batteries and "re-built" batteries can represent a serious safety risk. After purchasing a battery and associated compatible charger from one manufacturer, another may offer replacement batteries that are "identical to the original batteries", or offer to re-build your original batteries to "like new" conditions. Such replacement or re-built batteries are at best a misrepresentation and at worst a potential hazard.

Replacement, look alikes or re-built batteries may 'appear' identical to the original, and often re-use or copy the original manufacturers' cases, however the internal components, assembly techniques and quality control are almost always quite different. In addition, the cell type and formulation is almost always different from the original for which the charger has been optimized.

Unfortunately such hidden differences do not become evident until it is too late. Initially these "replacements" or "re-builds" only appear to be "equivalent", while the internal differences will eventually result in reduced performance and a life span that is usually only a portion of the original battery. Most critically, these internal differences pose a serious safety risk that have resulted in fire and explosion.

Having invested in a safe and compatible battery/charger system, it is hazardous (as well as uneconomical) to utilize batteries not produced by the original manufacturer.

PORTABLE LIGHTING

The latest video camcorders are technological marvels that bear little resemblance to the crude tube devices of the seventies. With the evolution of advanced CCD chips, digital signal processing, and now digital recording formats, you would assume that video images being viewed today are quite superior to those of a decade ago. Unfortunately this is often not the case.

The camcorder only records the image; it is light that creates the image. Today's cameras have such high sensitivity and low noise that cameramen are encouraged to shoot with available light in almost any situation. The problem, however, is not the *quantity* of light, but rather the *quality* of the light.

Available light almost always involves illumination source – whether ceiling fixtures indoors or the sun outdoors - coming from above. While this type of illumination is satisfactory for the background, it creates a disaster with a person in the foreground. The horrors of available light are familiar to everyone: dark eye sockets, glowing noses, giant chin shadows, radiant foreheads, and exaggerated wrinkles. It's not a pleasant sight.

An elegantly simple solution to this available-light problem has now gained wide spread popularity. It is a tiny camera mounted 'fill light' that is designed to perfectly fill and thus remove the shadows created by overhead lighting. The concept for such a light is easy to understand. According to architectural specifications and actual location measurements, virtually all interior locations are lit to within one f-stop of 40 foot candles. A survey of video professionals further revealed that the vast majority of ENG 'stand-ups', interviews, and foreground action always occurs within 1 to 2 meters of the camera. The perfect fill light must thus produce about 40 fc at approximately 1-2 meters (5 ft.) with a beam angle sufficient to cover all popular lenses.

The 50+ watt lights often used today are not much better than the 100 to 250 watt bulbs used 15+ years ago. These lights totally overpower the subject with an unnatural search-light effect reminiscent of interrogation scenes in 1940s movies.

A light output greater than 40 fc on the subject from the camera position overpowers the available light creating the flattening "searchlight-in-the-face" look and also causes the lens to iris down making the background muddy. Likewise, significantly fewer than 40 fc of light from the camera will not effectively remove the shadows which are, by definition, those areas that are not receiving the 40 fc of available light from above.

Studio lighting "models" the subject with light from both the front and above in comparable proportions - which is exactly what the "40 fc perfect fill" can do in conjunction with the existing architectural light. The proper fill light is one designed to work *with* available light to create studio quality video.

The subtle 'fill' from this light perfectly matches the existing available light and miraculously removes all offending foreground shadows without affecting background clarity or exposure. No verbal account can begin to describe how this simple 'fill' can instantly transform any available light location from a shadowy nightmare to an apparently 'studio lit' scene.

By utilizing a high efficiency and precisely angled reflector, the Anton/Bauer Ultralight consumes 30% less power than conventional lights of equal illumination. As a result the required 40 fc of light is achieved with *only 25 watts*. (It' is clear why those old 250 watt lights were so horrible; they were using 10 times too much power.)

With such low power drain, the Ultralight can be powered from the same battery that powers the camera or camcorder. Such a configuration eliminates the need for dangling cables or additional battery belts. A PowerTap socket allows the light to be plugged directly into the Anton/Bauer Gold Mount at the rear of all professional cameras. (Many professional cameras include the Gold Mount directly from the manufacturer, however there is a Gold Mount available for most every camera and camcorder). The additional current drain of the light should not have a significant impact on battery run-time since the light is not on at all times the camera is on. A battery providing 2 1/2 hours of operation will still typically deliver almost 2 hours with an Ultralight in a typical ENG situation.

This fill light is not an "accessory" for an ENG/EFP camera but rather a "necessity" for professional quality video and most major professional cameras/camcorder manufacturers are now making such fill lights an integral part of the camera design. Working in close cooperation with camera/camcorder manufacturers, the ULTRALIGHT 2 can be controlled automatically by the VCR 'Rec' button to turn on and off simultaneously with the VCR. This Automatique™ feature eliminates wasted battery capacity and, together with the low power consumption, allows this light to be powered directly from the camera battery without any significant reduction in camera run time. When it comes time to put the camcorder back in the case, or if the light is not needed, the lamp base folds into the handle and completely disappears.

The use of a 25 watt 'fill light' powered from the camcorder battery should not have a significant impact on the selection of your battery/charger system. In most cases the battery system recommended for a specific application will not be changed by the addition of a low power fill light. However, the following guidelines should be considered when using a camera mounted and powered light:

1 - Do not 'cheat' on the aforementioned 2-hour minimum run-time objective. The watt-hour capacity of the battery should be a minimum of 2 times the power consumption rating of the camera/camcorder.

2 - You may want to consider a battery system consisting of two different size batteries. A larger capacity, heavy duty type for indoors where fill light is needed, and a smaller capacity for outdoors assignments. As an example, a 25 watt camcorder should be matched with a 50 watt hour battery. While a HyTRON 50 (50 watt hours) may be quite satisfactory for a fast paced outdoor (no light) assignments, a HyTRON 120 would be a better power choice when a fill light is being used.

3 - The additional power drain of a fill light is relatively insignificant except when the cameraman inadvertently leaves the light on when tape is not running. It is important therefore to develop the habit of turning the light off immediately after the tape is stopped. The Ultralight Automatique feature is a standard feature of almost every professional camcorder today and built directly into the camera's Anton/Bauer Gold Mount to couple with the VCR 'roll' circuit in the camera. The light can be controlled manually or automatically, turning on/off with the VCR button on the camera eliminating wasted power.

4 - For greater distances from the camera to the subject, additional light output may appear to be needed. However in most cases this does not mean that a higher wattage bulb is necessary. Utilizing 'spot' type bulbs and focus adapters, the light output can be increased by more than *10 times* with little no increase in wattage. When distance between camera and subject increases, the lens is usually at a longer focal length, or more narrow, viewing angle. By matching the beam angle of the light to that of the lens, an enormous percentage of the light that would otherwise be wasted is now concentrated onto the subject.

While the 25 watt bulb will cover the vast majority of interior 'fill' situations, there are several instances where additional wattage and light output may be required. These include the following:

1 - Outdoor "Daylight Fill" - In many cases a subject outdoors will be in an area or position that is getting less light than the background or one side of the face may be more highly illuminated than another. This is basically the same situation as indoor fill except the illumination level to be filled may be 20 or more times as bright. This situation can typically be addressed by an 85 watt spot (narrow beam angle) with a dichroic 'daylight' color correction filter. Such an arrangement, which is almost equivalent to an old inefficient style 30 volt 250 watt 'sun-gun', can typically provide an "f- 8" lens stop at a reasonably close distance. High efficiency, low wattage HMI lights, such as the Anton/Bauer UltraDAYlight head module, can deliver more than twice the footcandles at 5600°K for the same power as tungsten sources.

2 - Distant Interior Wide Angle - The 25 watt 60° beam angle universal fill light can cover an individual or typical "two-shot" (interviewer/subject) at any distance up to about 10 feet (3 meters) with even the widest viewing 4.8mm lens. However, to cover a larger group of people (wide angle lens) at distances of 13 to 20 feet (4-6 meters) will require an 85 watt flood set-up (an 85 watt flood bulb or 85 watt spot bulb with wide angle adapter). In those rare instances where a large group at 20 or more feet from the camera must be covered, a quick switch to a 200 watt 30 volt head module may be required. Such a bulb can be powered by a standard "30 volt" (28.8 volt) battery belt, or two regular ProPac 14 video batteries with a special "30 volt" lighting holder.

3 - Exterior Night - The most prolific mis-use of high wattage lights occurs at night covering "disaster scenes". Contrary to the popular conception, less light should come from the camera as an exterior scene gets darker. Due to the recent advances in camera technology, high-voltage/high-wattage lights in these situations will produce flat video and destroy background detail. Greater realism, clarity, and overall quality can usually be achieved with lower power 25 watt bulb even if 6 dB or 9 dB of gain is necessary.

***PROBLEM APPENDIX** (with Solutions)*

Batteries appear to be the most misunderstood aspect of professional video, possessing a "complex personality" that over the years has spawned an extensive popular mythology that unfortunately is more fiction than fact. This has led to a large number of battery problems that has compromised many a video production. Throughout this handbook we have attempted to clarify most of these misunderstandings in a practical and topical manner.

The following addresses more fully the most widely discussed and misunderstood rechargeable battery problem topics.

MEMORY

NiCd "memory" is probably the most widely misunderstood of all battery anomalies.
The introduction of new chemistries has led to a great deal of talk about any new battery being "memory free". As we will see, many of the same phenomena which have resulted in the label "memory" in NiCd can exist in both NiMH and lithium ion. In fact, most of the talk of memory comes from those manufacturing or using the wrong batteries and chargers for the application.

A major source of the confusion surrounding "memory" stems from the fact that there are two totally separate phenomena that have been called "memory". One of these is the "true" memory phenomenon which virtually never exists in practical application. The other is actually a 'voltage drop' problem that has become known as a "memory" problem based on its symptoms. It is this voltage drop that has been the long time subject of "memory" myth in the video industry.

The "true" memory was first observed by NASA while monitoring an orbiting satellite. Each day at precisely the same times, this satellite alternately passed from sunlight, where its NiCd batteries (not the same type as used in batteries for professional video) were solar charged, into darkness, where the batteries were called upon to power the craft. After many cycles of this precise duration partial discharge/charge routine, the scientists found that the battery would refuse to deliver power beyond that point to which it had previously been repetitively discharged. In other words, the battery "memorized" the point of partial discharges and then refused to give energy beyond that point if called upon to do so. This story has given rise to the myth that batteries should always be fully discharged before being charged in order to prevent the mysterious "memory" from robbing the remaining capacity.

This type of memory never occurs in the video industry or any other industry for that matter. This rare memory phenomenon only results when the amount of the repetitive partial discharge is precisely identical each time, as occurred in the satellite. Relating this to video, a battery would, for example, have to be discharged for exactly 23 1/2 minutes at the exact same rate each day and then recharged each night for a week or more before this type of memory developed. Clearly nothing even close to this could ever happen. Yes, batteries are frequently only partially discharged and then recharged, but never in the precise manner necessary for true memory to be developed.

The "memory" so often mentioned in the video industry is not really a loss of capacity nor does it result from repeated partial discharges. It is in reality a voltage depression phenomenon and fig 5 is a graphic representation. At the so-called "memory" depression point, the voltage of the battery will drop about 1.2 volts. Figure 5 curve 'A' represents a "12 volt" nominal battery on a typical camcorder. Note that at the "memory" point the battery voltage drops below the camera cut-off voltage and thus the camera will stop. It appears that the battery has no more capacity. However this is not true. As can be seen, the battery can still deliver full capacity to the specified EODV at this lower voltage without a problem. The problem is the camcorder, which can not use this capacity. (Called "unavailable capacity". See also Battery Voltage section). This is why this type of "memory" became known as a "loss of capacity", because in this misapplication it does indeed result in a loss of capacity.

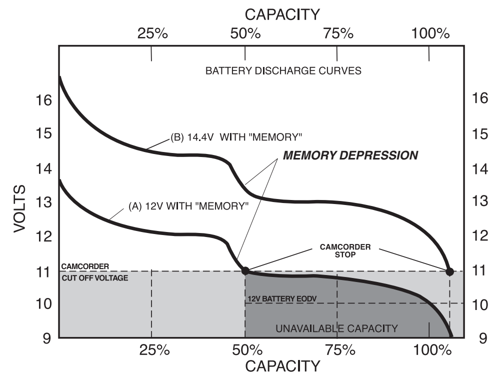


Figure 5

Curve 'B' represents the proper "14.4 volt" nominal battery for this camcorder. Note that the so-called "memory" point and associated voltage depression results in no loss of capacity. So this type of "memory" really is not a "loss of capacity". But where does this voltage depression come from and why is it called "memory", and why do so-called dememorizers or dischargers seem to alleviate this problem?

This so-called "memory" problem may be traced to a "transformed" or secondary alloy of Nickel Cadmium which can be developed under extremely poor charging conditions. Very simply, when a fully charged NiCd battery remains on a slow charger or many fast chargers, it is receiving a 'trickle charge' which is designed to prevent self discharge. Unfortunately over a period of time, this trickle charge can gradually transform the crystal structure a portion of the nickel and cadmium plates into secondary alloys. While a normal NiCd has a nominal voltage of 1.2 volts per cell, these secondary or "rogue" alloys produce a lower characteristic voltage of approximately 1.08 volts per cell.

Now consider a 10 cell (12 volt) VTR type video battery that has developed some of the transformed alloys. It is really two-batteries-in-one: part of the battery is a "12 volt" nominal NiCd and the rest is a "10.8 volt" nominal secondary alloy. When this "dual voltage battery" is placed on a camcorder, the power will always be drawn from the higher voltage section (normal) first and everything appears normal. Once the normal plate chemistry has been discharged, power will begin to be drawn from the lower voltage alloy section of the plates. Of course at this point the voltage will fall to the characteristic voltage of the transformed alloys, which is insufficient to keep the camcorder operating.

There appears to be a mysterious loss of capacity and the battery is returned to the charger. The question now is: "What is being recharged"? The answer is: not the rogue alloy parts of the battery. Because the camcorder could not discharge the transformed chemical structure of the battery, it is still fully charged and intact. Only the "normal" section of the battery is being recharged. Therefore, the next day the battery will perform exactly as it did on the previous.

First, everything will appear normal and then all of a sudden the camcorder will mysteriously stop at the same point as it did before as if it had "memorized" the point at which the capacity was lost. This is where the misnomer "memory" comes from. Likewise, this is where the myth of the discharger was born giving rise to the totally false notion that batteries should be discharged fully before being charged.

Now that the mysterious phenomenon of "memory" is understood, the principle of the discharger becomes apparent. Because the camcorder can not discharge the rogue alloy in a "12 volt" nominal battery, it will remain there "forever". As a matter of fact, the situation actually gets worse as each subsequent trickle charging will create even more rogue alloy. In reality the rogue alloy is a perfectly legitimate battery. If the afflicted battery is connected to a device that can properly run down to the correct full discharge voltage of 10.0 volts, the battery will be *totally* discharged, rogue alloy and all. Now when it is recharged it will be 100% normal NiCd and the missing capacity magically returns. Thus the creation of the "discharge-before-charge" myth is as follows:

1 - A camera/camcorder is powered with the wrong battery that has a full discharge voltage *below* the cut-off voltage of the camcorder.

2 - When trickle charging creates the rogue alloy, the camcorder can not discharge it. Thus the rogue alloy remains intact and the battery appears to progressively lose capacity.

3 - By placing the battery on a device that can discharge the rogue alloy, the battery becomes 100% normal alloy when recharged and the "lost capacity" miraculously returns.

Take another look at fig 5 Curve 'B'. Note that when the correct battery with the proper voltage range for the camcorder is used, there is no "memory" problem. In essence, the camcorder performs the function of the "dememorizer" or discharger by fully discharging and erasing the rogue alloy every time the battery is used. It should be absolutely clear that the "memory" problem and the associated 'discharging-before-charging myth' are both the result of using a "12 volt" nominal battery in applications calling for a "14.4 volt" nominal battery. Moreover, when using the proper voltage battery, discharging fully before charging is not only unnecessary, it is not recommended (See section below).

DISCHARGE-BEFORE-CHARGE

The above section on "memory" fully explains the origin of the discharge-before-charge myth and why it is unnecessary when using the correct battery for the application. However if a discharger is currently being used to test a battery performance in the field, it is imperative that precautions are observed to avoid permanent damage to the battery and possible explosion.

A light bulb or resistor must never be used as an unmonitored load to discharge a battery as this will take the battery down to 0 volts. Fully discharging a battery to 0 volts may damage the battery irreparably and could cause a serious explosion. A video battery consists of ten or more cells in series. As a battery approaches the end of discharge, one cell will always reach total depletion before the others. Once this first cell reaches 0 volts, the remaining cells may still have some energy and will continue to deliver power to the load. This current passes through the depleted cell and will actually begin to charge the depleted cell in the wrong direction. This drives the cell into reverse polarity which will damage and weaken the cell as well as create explosive hydrogen gas.

When applied to rechargeable batteries the expressions “full discharge” or “deep discharge” never mean a discharge to 0 volts but rather a discharge to the specified EODV or End of Discharge Voltage (sometimes called the ‘full discharge voltage’). Therefore a discharger must have an automatic cut-off set at the EODV of the battery or slightly below. When the battery voltage reaches this value, the load must be instantly disconnected from the battery to avoid damage and injury.

For reference, the EODV voltages recommended for discharger cut-off are:

“12.0 volt” nominal battery = 9.0 to 10.0 volts
“13.2 volt” nominal battery = 10.0 to 11.0 volts
“14.4 volt” nominal battery = 11.0 to 12.0 volts

Remember: When using the correct battery for an application, discharging before charging is not only unnecessary, it is *strongly not recommended.* Such discharging serves no purpose other than to detracts from the overall cycle life of the battery.

For those who continue to ‘believe’ in the existence of “memory” problems despite the afore-mentioned scientific evidence to the contrary, the following suggestions are offered:

• Feel free to “exercise” your batteries every month or two by using a discharger with the proper cut-off circuit. After the discharge is completed, allow the battery to ‘rest’ for at least 2 to 4 hours before being recharged. Such an occasional discharge should have no significant adverse effect on the battery.

• Place ‘name labels’ on your batteries such as “Monday”, “Tuesday”, etc, or just “A”, “B”, “C”, etc.

On Monday, begin with the “Monday” or “A” battery and try to use it until depletion (low voltage warning in the camera), and then switch to any other battery. On Tuesday, start with the “Tuesday” or “B” battery and again try to use it until depletion before changing to any other battery.

Continue in this manner each successive day. This practice will guarantee that each one of your batteries will receive a full discharge *during operation* at least once a week. For those who feel for some reason that periodic discharging is beneficial, this is the safe and practical way to do it without reducing the life or performance of the batteries. In essence, by using the proper voltage battery, the camera performs the function of the perfect discharger.

SELF DISCHARGE

A fully charged battery, after it is removed from the charger, will experience a phenomena known as self discharge. Due to an internal characteristic of any rechargeable cell, it will very slowly and steadily lose its charge over a period of time. At room temperatures, a NiCd or NiMH battery will be expected to typically lose up to 5% of its capacity in the first 24 hours and then about 1% each day thereafter. Under normal circumstances self discharge can be considered insignificant as almost 90% of full charge capacity should be available after more than a week away from the charger.

Lithium ion batteries will retain a greater degree of their charge for a longer period. However, it should be noted that the charged state is the worst condition to store batteries long term, especially lithium ion. The effects of “unrecoverable capacity” (discussed in the Cell Formulation Section) are significantly worse in a charged battery. While the effects of storage are virtually nil in a NiCd and less in a NiMH, long term storage of a lithium ion battery should be avoided. Colder temperatures will significantly slow the process for all batteries while elevated temperatures will accelerate self discharge.

The effects of self discharge can be fully negated by employing an InterActive charger with its Lifesaver maintenance mode. This proprietary program provides only the appropriate amount of low rate charge sufficient to offset the self discharge rate of the battery. In this way the batteries can remain indefinitely on the charger, 100% charged and free from the deleterious effects of self discharge and resulting cell imbalance.

IMBALANCED BATTERIES

An imbalanced battery is characterized by having individual cells in the battery pack that are at different states of charge. This results from the fact that of the ten or more cells that make up a nickel based battery, each is likely to self discharge at a slightly different rate and over a period of time each cell will exhibit a slightly different capacity or state of change. This minor problem becomes major when one or more cells exhibit an anomaly known as accelerated self discharge in which case the magnitude of the imbalance can become extreme and render the battery useless.

A lithium ion battery may also become imbalanced due to various factors - manufacturing tolerances when the cell was made, mismatching of cell capacities when the battery pack was made, extended storage periods resulting in cells of different “recovered capacities”, internal failures in one of the cells, or by varying loads placed on the cells created by the battery’s own monitoring circuitry.

Unfortunately, it is impossible to address an imbalanced lithium ion battery. Assuming the safety circuits of a lithium ion pack are properly designed and operating, the lower capacity of even one cell in a pack can drive the entire pack to shut itself down. Since only one cell at EODV will shut down the pack (and therefore the camera) any imbalance in a lithium ion battery creates a shorter run time. The weak cell may also shut down charge to the entire pack when it is fully charged and the rest of the pack is only partially charged. The resulting spiral of poor performance is but one drawback of lithium ion chemistry. The following discussion relates to nickel based chemistries only.

Cells with some level accelerated self discharge are quite common and the above course of events occurs all too frequently, however this need not happen. Batteries with such cells can provide satisfactory service if the correct measures are taken. Of course proper battery construction can effectively eliminate the major cause of accelerated self discharge but when this condition does exist, accelerated self discharge can be negated (only in nickel based chemistries) with a *maintenance charge* and any imbalances can be corrected with a special *equalizing charge*.

Equalizing Charge - Due to both normal and accelerated self discharge, a battery can become imbalanced (see above). Conventional charging can not address this problem as the fast charge current must be terminated when the first cells reach full charge otherwise they would be damaged. Any other cells that have not reached full charge at this point will remain in the less-than-fully-charged condition. Thus any imbalance that existed before charging will still exist after charging. In addition, conventional charge termination technology can be totally mislead by a severely unbalanced battery and fail to cut-off high rate charge current resulting in battery destruction and the risk of fire.

This apparent paradox and hazard has been eliminated through InterActive charge technology. No matter how severe the imbalance, the internal sensors in the battery will always identify the first cell reaching 100% charge and terminate the fast charge thus eliminating all risk of hazard and damage to the cells. Immediately after the fast charge current is terminated, the charger microprocessor enters the *equalizing mode.* Based upon data from the battery Microcode circuit and sensors, and charge data collected during the preceding fast charge cycle, the battery receives an equalizing charge cycle that consists of a precise charge rate designed to bring up to 100% those cells requiring additional charge while causing no damage to those cells that have already reached full charge. When *all* cells have reached 100% charge and the battery is fully balanced and equalized, the equalizing charge rate is terminated and the *maintenance mode* commences. When using an Anton/Bauer InterActive charger, this *equalizing mode* is a standard feature of every charge cycle thus assuring complete safety and a 100% charged and balanced battery every time. While the *equalizing mode* can correct any existing imbalances, the *maintenance mode* is designed to prevent imbalances from ever developing.

Maintenance Charge - Assuming a conventional charger has successfully identified the full charge status of the battery and terminated the fast charge current, it will classically do one of two things. It will either shut off all charge current (and essentially disconnect from the battery) or provide a continuous ‘trickle charge’ for as long as the battery remains on the charger. Both of these alternatives create serious problems.

Terminating all charge current is identical to removing the battery and placing it on a storage shelf until it is needed. This allows the cells within the battery to experience both normal and accelerated self discharge, as the case may be, which creates the highly undesirable scenario described in “Imbalanced Batteries” above. Even if accelerated self discharge is minimal, normal self discharge can still rob a significant amount of run-time depending on the storage time before use and the storage temperature.

After fast charge termination, many conventional chargers place the battery on a continuous ‘trickle charge’ for as long as the battery remains on the charger. This trickle charge is designed to fully compensate and thus negate virtually all self discharge, both normal and accelerated, keeping the battery fully balanced and charged. This concept is valid in theory, however the trickle charge unfortunately has serious side effects that are actually more detrimental to the battery than self discharge. Trickle charging creates heat that will elevate the cell temperature of a typical video battery to over 45˚ C (113˚ F) which causes the cell to deteriorate at a rate 5 to 10 times faster than normal. In other words, the constant trickle charge is causing the battery to age up to 10 times faster than normal, and a battery that would be expected to provide 2 or more years of service may fail after only 3 months of use. In addition, these elevated temperatures also reduce charge acceptance resulting is reduced capacity. Lastly, extended trickle charging is the major cause of the phenomenon known as "memory". The bottom line is that trickle charging is one of the worst things you can do to a battery, from both an economic as well as a performance perspective.

This is the proverbial "damned if you do and damned if you don't" situation. If the battery does not receive a some charge, it will self discharge and become imbalanced. On the other hand, if the battery is given a trickle charge, self discharge and imbalances are prevented but performance will be impaired and battery life can be reduced by 80%. Confronted with this paradox many years ago, Anton/Bauer developed a maintenance charge regime that could prevent self discharge and imbalances without the heat generation and accelerated aging associated with conventional trickle charging. After the battery has been charged and fully balanced by the equalizing mode, the battery is placed in the exclusive Lifesaver *maintenance mode* for as long as the battery is on the charger. The microprocessor, with data from the battery, creates the precise Lifesaver pulse profile to keep the battery 100% charged and balanced with virtually no temperature elevation or accelerated aging. The battery should remain on the charger until it is needed. This can be days, weeks, or even months.

TECHNICAL UPDATE: FUEL CELLS

Fuel cells may very well represent the future of portable power. In 2003 the Bush administration backed almost 2 billion USD to fund research, infrastructure development and R&D of hydrogen energy technologies.

A fuel cell is essentially an "engine" which converts hydrogen and oxygen into electricity and water. By no means a 21st century technology, the first fuel cell was invented in 1839 by Sir William Grove about 40 years after Alessandro Volta invented the first battery. In the early 1960s GE made the first PEM (polymer electrolyte membrane) used in the Gemini spacecraft.

Recently fuel cells have received a widespread buzz with a great deal of discussion of the "hydrogen highway" and the "hydrogen economy". Hydrogen unfortunately does not normally appear by itself in nature but rather as part of other compounds and therefore must be extracted or re-formed. Indeed the benefits of finding efficient methods of reforming hydrogen are inescapable – a virtually limitless supply of fuel which can be used in energy producing devices from which the only by-products are essentially energy and pure water. However today this reformation process requires substantial amounts of fossil fuel to extract hydrogen and there is little infrastructure to process, store and deliver hydrogen as an alternative energy source. Thus, more energy from fossil fuel is required to reform and deliver Hydrogen than hydrogen can yeild.

As the digital revolution beginning in the 80's led the improvement of batteries, the development of alternative energy transportation technology is driving the development of fuel cells. So the research and development has been largely focused on the automotive industry where size, weight and cost are not as critical as in portable appliances – such as computers or camcorders.

Fuel cell technology may become increasingly important as the cost of fossil fuels increase and its supply decreases and a fuel reformation methodology is developed to economically support the supply of hydrogen (or other fuels). In the meantime there will be a great deal of effort made to show that fuel cells could be a viable alternative energy source, in an attempt to jump start a new energy paradigm – the release of the "hydrogen genie". Along the way, though, there will be a great number of very practical hurdles to overcome.

The following discussion addresses some of the questions we have been asked regarding the application of fuel cells to professional video.

Entry Cost. A PEMFC of about 60 watts with a fuel supply capable of about 140 watt hours of operation can be expected to cost about 3-4 times that of a battery supplying the equivalent runtime. A 60 watt 6.5 lb fuel cell, a couple of fuel blocks, and the re-fuelling plumbing to hook up to a regulated hydrogen tank would cost well in excess of two to three times that of a comparable battery and charger system.

Ongoing costs. Because hydrogen, the most common element in nature, does not occur by itself in nature, it must be "re-formed" from another source. Today that source is primarily a by-product of burning natural gas. Stored hydrogen is not cheap. The cost of bottled hydrogen is many times more expensive than electricity obtained from the power companies. A 2 lb. 140 Wh hydride canister would cost about 50¢ to fill from a hydrogen tank. The cost to charge a 160 Wh battery is less than 6¢ or almost 10 times less. Over 500 operating cycles refilling a PEMFC fuel block will cost more than $250. Methanol in solution may ultimately be a viable and economical fuel, but for now, the cost of fueling a fuel cell still cannot compete with the economics and global accessibility of electricity. Longevity of a PEMFC has yet to be determined in field operation.

Size. A PEMFC capable of supplying 60 watts for about 2 1/4 hours (140 watt hours) would be about 150 cubic inches (1.64 liters). A battery capable of similar runtime (and much greater load capability) is about 80 cubic inches (1.29 liters) or about 46% smaller.

Weight. The same theoretical PEMFC as above might weigh about 6.5 lbs (2.95kg). A battery capable of similar runtime (and much greater load capability) would weigh about 3.5 lbs. (1.59kg) or about 46% lighter.

Convenience. The PEMFC used in the above examples *could* power a typical 25-35 watt camera. However, *regardless of the operating need*, the operator is *always* required to carry 6.5+ lbs on the camera… even for a 5-minute shoot. As well, the identification of hydrogen sources becomes an added logistic issue to the planning for any location production. Filling 2 lb hydrogen fuel blocks from a high pressure gas bottle likely will not be permissible in a hotel room.

Lack of supporting infrastructure. The fuel source to charge a battery is one of the most ubiquitous in the world – electricity. There is no corresponding infrastructure for the supply of hydrogen or other fuels such as methanol. While bottled hydrogen can be obtained in most major cities in purities required for fuel cells, it typically will not be sold to individuals. A high pressure (~2200psi) storage tank requires a regulator and piping for safe handling and refilling of a PEMFC hydride fuel block.

Performance. Operating conditions are extremely important to a PEMFC. Humidity, for example, needs to be within a very tight range to keep the membranes critical to the operation of the device from either drying out or saturating with water. Dust can also be a problem. Temperatures below 30°F and above 100°F are prohibitive to fuel cell operation. Today's prototypical PEMFCs can not compare to the durability, wide range of operating conditions and load capability of a professional video battery.

Efficiency. Today's fuel cells are relatively inefficient, capable of delivering only a portion of their potential especially those that operate in ambient environments; that is, without forced air or oxygen feed. A portable ambient air PEMFC design could be expected to supply about 60 watts but at almost double the size and weight of a battery that is capable of supplying almost three times the output.

Operating limitations. The theoretical example PEMFC above at 60 watts could likely be capable of short duration maximum loads of around 75 watts. Any more, and depending on the construction and electronics in the device, the device would "fold back" much as a AC mains adapter (power supply) will do if overloaded – essentially shutting down. A 45 watt camera and a 50 watt light are well beyond the capability of any small fuel cell product currently contemplated. This limitation makes the PEMFC unsuitable for professional video applications, including any combination of high wattage camera (>25 watts) and peripherals such as on-board lighting (25-85 watts). By contrast the example battery above will power *continuous* loads of up to 140 watts or 180% more load capability.

Transportation restrictions. Unlike restrictions governing size or quantity for certain batteries (like lithium and lithium ion) <u>all</u> practical fuels (hydrogen, methanol) for fuel cells are restricted in their transport. For example, hydrogen stored in any form, including hydride bottles, is currently not allowed in passenger compartments of aircraft and must be transported under special manifest as a flammable gas, solid (for hydrides), or liquid (methanol). While this may change as methods of producing reliable storage devices are improved, at this time travel and shipping logistics – air and rail – are severely limited.

The following pages compare a PEMFC to a field proven Ni-MH and lithium ion batteries. Service life cannot be compared as the longevity of PEMFCs have yet to be proven in field use. The promise of improvements in fuel cell products and the development of a worldwide re-fueling infrastructure may provide a reasonable alternative in the future for batteries. Until then, the performance, cost, size, weight, service life and proven reliability of a professional video battery are beyond the capabilities of today's early fuel cell designs.

A PEMFC product versus HyTRON 120

145 watt hours FUEL CELL	120 watt hours BATTERY	**COMPARISON**
		+25 watt hours
6.7 lbs	5.5 lbs.	+1.2 lbs
150 cu. in	75 cu. in	+75 cu. in
CHARGE COST ~$.50/cycle	~6¢/cycle	~$.40/cycle*
MAX POWER 60 watt	175 watt	-110 watt

Fuel cell difference:
25 more watt hours achieved at:
- TWICE the size
- 22% more weight
- about 10 times more operating cost
- 65% less load capacity

***500 cycles = $200 more operating cost**

A PEMFC product versus DIONIC 160

145 watt hours FUEL CELL	160 watt hours BATTERY	**COMPARISON**
		-15 watt hours
6.7 lbs	3.4 lbs.	+3.3 lbs
150 cu. in	79 cu. in	+71 cu. in
CHARGE COST ~$.50/cycle	~6¢/cycle	~$.40/cycle*
MAX POWER 60 watt	145 watt	-80 watt

Fuel cell difference:
15 *less* watt hours achieved at:
- TWICE the size
- 97% more weight
- about 10 times more operating cost
- 57% less load capacity

***500 cycles = $200 more operating cost**

How does one determine which battery is "best"?

It is important to recognize that choosing a battery system today is as important a decision as deciding on a recording format. In most cases the choice of batteries outlasts the choice of cameras. Many broadcasters who started with NPs when the very first BetaCams appeared (because they got them "with the cameras") are still dealing today with problems which were successfully eliminated by Anton/Bauer 20 years ago.

The "best" battery is one which can be consistently and dependably used in every way the operator wishes to use his equipment. The battery to power a 40 watt digital format camera with an on-camera light is not necessarily the same battery to power a 25 watt camcorder without a light.

A battery system, with features adopted by every major equipment manufacturer, consisting of batteries of multiple sizes, chemistry and cost that can all be addressed on a single upgradeable charger is the only "universal" solution. Ultimately, each application and operation is different and should demand different battery types.

Ask the right questions:
- Which battery format offers the most flexibility and compatibility with today's equipment?
- What sizes and types fit the type of shooting that I do? Do I only do one type of videography?
- Can I mix different sizes and chemistries on the same charger?
- Can I effectively operate on-camera lighting?
- Which format and battery type is the most cost efficient? Determine both the initial cost and the cost over time to operate and replace batteries?
- Which battery format can adapt to new technologies as they arrive?

No one battery in video, or in any industry, can be called "universal". In a video operation different operating conditions, different shooting requirements and individual preferences call for different batteries at different times. The days of having only one size or type of battery have long past.

Today the decision of which battery to use in professional video is one of format. A battery format which offers the technology of a wide variety of sizes, types and chemistries, which can be used on equipment from any manufacturer, and which offers the ability to mix and match batteries safely and reliably on a single charger - now and in the future.

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Due to continuing product development, all specifications and prices are subject to change without prior notification.

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