LIFE CYCLE COSTING FOR BATTERIES IN STANDBY APPLICATIONS

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Abstract - The economics of a battery system comprises not only the initial cost, but also the cost of installation, maintenance, testing and disposal. In many cases the initial cost gives a very misleading impression of the total cost of the system during its lifetime. Thus, in reality, the total cost of the system over its lifetime, or life cycle cost, needs to be established in order to have a true economic analysis.

A computer program, running in MS Windows, has been developed to generate life cycle costing for batteries and it takes into account labor and material costs for procurement, installation, annual maintenance and disposal. It also includes individual labor costs for the different tasks, annual inflation, the effect of temperature and, where appropriate, the watering interval. The maintenance costs can be based on the IEEE recommendations or on the manufacturers/users specifications. The user can enter a cost for system downtime, if this is applicable to the installation, and a cost associated with catastrophic battery failure. All this is under the user's control.

The program calculates the annual cost of ownership of the battery for a chosen number of years and this is illustrated in a dynamic graphical format. The evolution of the ownership cost can be followed over the years and comparisons made between different battery types. The program is entirely 'open' in terms of input and does not favor a particular product type or manufacturer.

The paper describes the factors which have to be taken into account when carrying out life cycle costing and shows how this is applied in the software. Details and examples of the input required and the various outputs possible are given.

As an example, the VRLA battery is compared with the recombination nickel-cadmium battery to illustrate how the relative cost effectiveness of the two battery types depends on a number of factors including temperature, maintenance/replacement costs and the expected lifetime at room temperature. The comparison can be shown both graphically and in spreadsheet form.

Saft believes that this is a vital tool to help users make informed battery purchasing decisions. As a service to the battery industry, Saft is making the program available to battery users, and welcomes comments to help improve its usefulness.

1 INTRODUCTION

The life cycle cost of a battery is not simply a calculation concerning the initial cost of the battery and its lifetime. It is a complex calculation concerning the cost of installation, replacement, maintenance, testing, downtime cost etc. These other factors can be much greater than the initial cost of the battery and, looking at this factor only can lead to a very misleading, and costly, decision being taken.

This paper presents the factors, which should be taken into account in calculating a life, cycle costs and the computer program, which has been developed for this purpose.

2 LIFE CYCLE COSTING

The main factors which must be taken into account in a life cycle costing are the initial investment when the battery is installed, the replacement cost which is the sum of the costs involved if a battery has to be replaced, the on-going maintenance cost and the downtime cost which is the cost arising from either planned or unexpected loss of power.

The basic purpose of the Life Cycle Cost (LCC) program is to produce a realistic comparison between different battery options for a particular duty. The comparison may involve different battery chemistries, such as nickel-cadmium and valve-regulated lead-acid (VRLA), or it may involve subtler distinctions, such as comparing '10-year' and '20-year' vented lead-acid designs.

The program performs an LCC analysis to calculate the total cost of battery ownership. Rather than considering just the initial purchase price of the battery, as is normally the case, the program allows the user to include in the following additional costs:

- Battery rack or cabinet price
- Shipping Costs
- Installation labor
- Maintenance (manufacturer or IEEE requirements)
- Capacity testing
- Disposal
- System downtime cost generated by the non-availability of the battery during its replacement
- Unexpected battery failure cost (but this is indicative and not used in the calculation)
- Annual inflation (material and labor) is used to adjust future costs relating to material and labor.

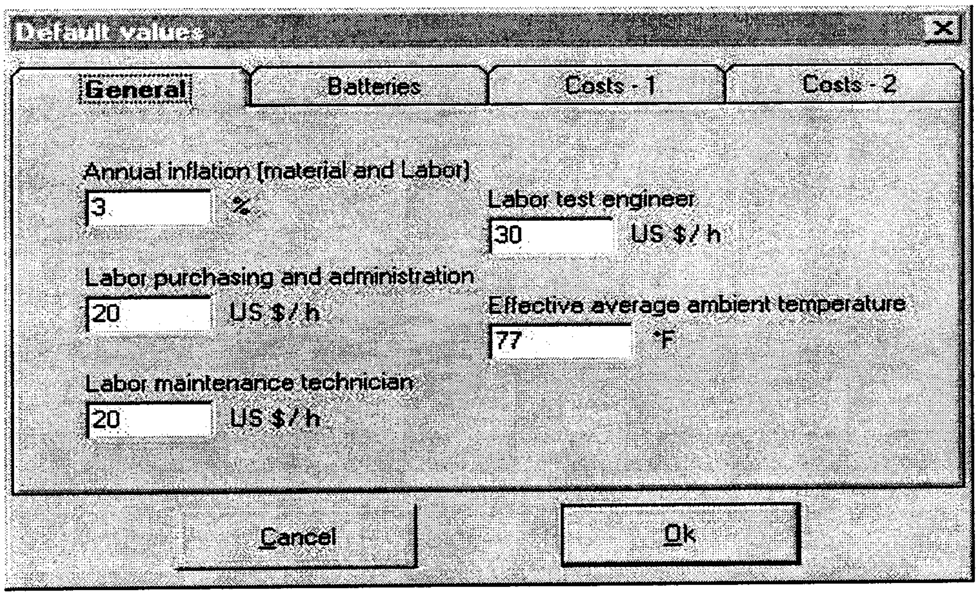

Figure 1: Default input screen

The default-input screen of the LCC program allows a certain number of basic costs to be input. The units can be modified between °C and °F, metric and US dimensions and weights and, also, the appropriate currency can be used.

2.1 The initial cost

The initial cost is the sum of the following factors:

Administrative/purchasing cost
Battery cost
Stands and connector cost
Transport cost
Storage costs
Installation costs
Commissioning and testing

2.2 Replacement cost

The replacement cost for a battery is not only the cost of the new battery. In practice, it is all the costs, which are described in "2.1 The initial cost", plus the costs associated with disposing with the old battery.

Thus, the replacement cost is as the initial cost, plus, for disposal:

- Administrative/purchasing cost
- De-commissioning of the battery
- Dismantling the battery
- Preparing for transport
- Transport cost
- Storage costs
- Disposal costs

An essential piece of information related to the replacement cost is the lifetime of the battery in the application. This determines if the battery would normally have to be replaced and, if it does have to be replaced, the number of times this will occur.

The lifetime of the battery can depend on many things, and these are discussed in section 3, Battery Lifetime

2.3 Maintenance cost

The maintenance of the battery can either be according to specified industry standards, to battery manufacturers recommended procedures or to user standards.

Whatever the maintenance procedures chosen, they will cover the following areas:

- Visual inspection
- Battery monitoring
- Mechanical checking of connections etc
- Water replenishment (if in product design)
- General cleanliness of installation

Within the life cycle cost calculation, it is possible to use two alternative methods to calculate the maintenance requirements.

These are the IEEE maintenance procedures and the manufacturers own maintenance procedures.

According to the method, the evaluation of maintenance operations is different.

In the case of the maintenance operations using IEEE recommendations, the standards used can be found in references (1), (2) and (3).

In the case of manufacturer maintenance operations used in the LCC, these take as references the recommendations of manufacturers and do not generally include testing of the batteries.

2.4 Downtime cost

The downtime can be of two forms: Planned downtime, where there is either a loss of facilities during the shut-off time or some back-up facility is put in place to ensure there is no loss in the facility, or unexpected failure, where there is a complete failure of the system and a complete loss of the facility.

3 BATTERY LIFETIME

The lifetime of a battery can depend on a number of items, the principle of which are:

- The technology type
- The temperature that the battery is subjected to in the application
- The number and depth of cycles required by the application
- How rugged the battery is in abuse conditions

Five battery families are proposed in the software: (NiCd ULM, Vented NiCd, Vented LA, Planté, VRLA) but others can be added.

One of the most important input parameters for this calculation is the battery life expectancy. For each battery under consideration, you are prompted to enter the life expectancy in the application at 25°C (77°F), taking into account any cycling requirements.

NOTE! In many cases, the battery warranty is not an accurate indicator of actual life. This is particularly true of VRLA batteries. If the life figure is not realistic, the calculation will not be valid.

A basic assumption is that, when a battery reaches the end of its life, it is replaced with another, identical, unit.

Based on the average operating temperature, the program employs basic electrochemical principles to adjust the life expectancy of the battery. For example, the accepted value for lead-acid batteries is that, for every 8°C (15°F) increase in battery temperature above 25°c (77°F), battery life will be reduced by 50%. For the same temperature increase, the equivalent life reduction for nickel-cadmium batteries is 20%.

This rule is based on an initial temperature of 25°C (77°F). Although there is some increase in battery life at lower average temperatures, it is a smaller effect and high-temperature effects tend to predominate. For example, a battery that is operated for 6 months at 35°C and 6 months at 15°C will have a shorter life than one that is operated for 12 months at 25°C.

The way in which the average operating temperature is calculated can have a major impact on the outcome of the LCC comparison. If the average annual ambient temperature for a geographical location is used, the battery life will probably be overstated, since the immediate battery environment is often warmer. However, the battery itself will tend to act as a heat sink and will not follow the extreme highs and lows of daily temperature swings. The biggest effect, however, is the balance of longer-term temperature variations above and below 25°C (77°F).

If there are no significant temperature swings below 25°C (77°F), it is valid to use the average battery temperature for a typical 12-month period. Where the winter and summer swings are more pronounced, however, a more realistic approach is to use the average battery temperature for the hottest 3-4 months.

4 GENERAL INPUT AND OUTPUT

4.1 Batteries

The battery input consists of the battery range, the cell type corresponding to the chosen battery range, the number of cells or block of the chosen battery and the weight per cell or per blocks of the chosen battery.
In addition, there is added an estimate of expected watering interval at normal temperature (the program automatically adjusts for elevated temperature operation) and an estimate of expected battery life at normal temperature (the program automatically adjusts for elevated temperature operation).

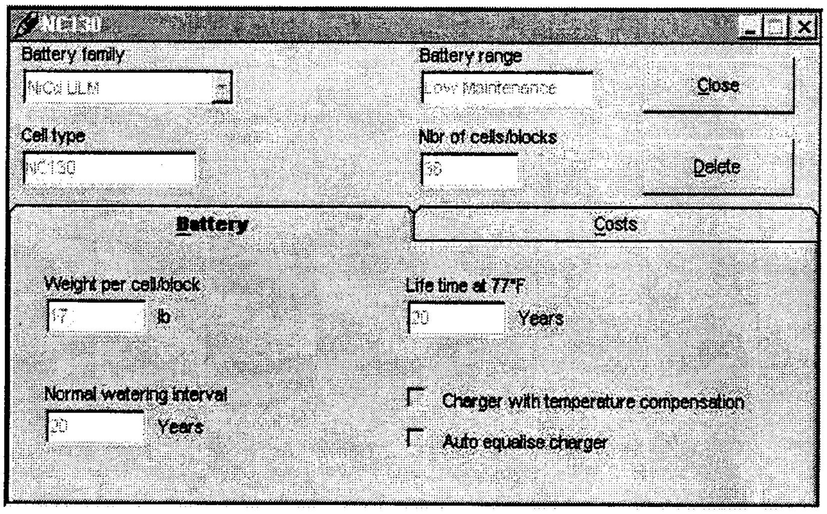

Figure 2: Battery details input window

4.2 Cost

The program allows the input of battery cost, rack or battery cubicle cost and charger cost (if required). The approximate battery local freight cost and the disposal cost are automatically calculated by the software equations whose coefficients can be changed. The calculated value can be modified if required.

4.3 Spreadsheet

The LCC spreadsheet gives the financial and operation variables, which are taken into consideration in the calculation of the life cycle cost, and the user input values.

The calculations given are disposal cost, annual maintenance cost (present) and total cost of ownership, which can be viewed every year over a 30-year period.

The spreadsheet doesn't take into account the residual value of a relatively new battery.

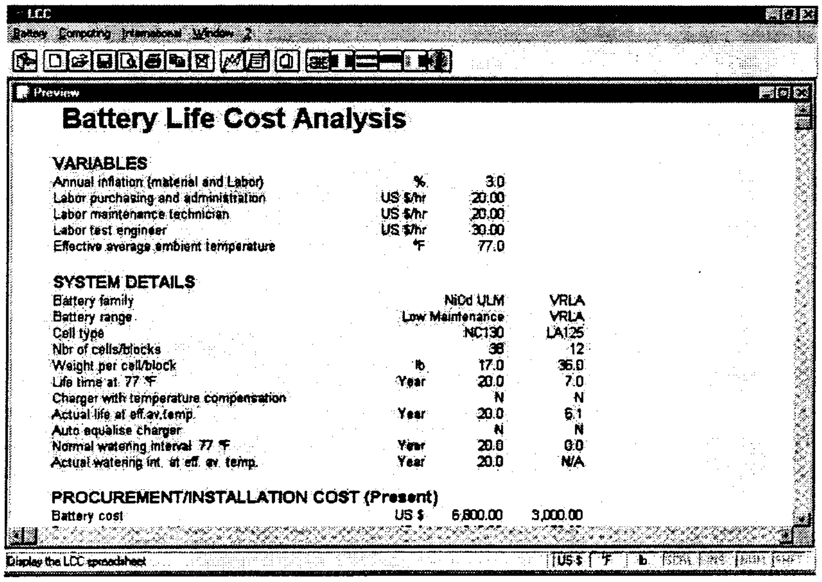

Figure 3: LCC spreadsheet output

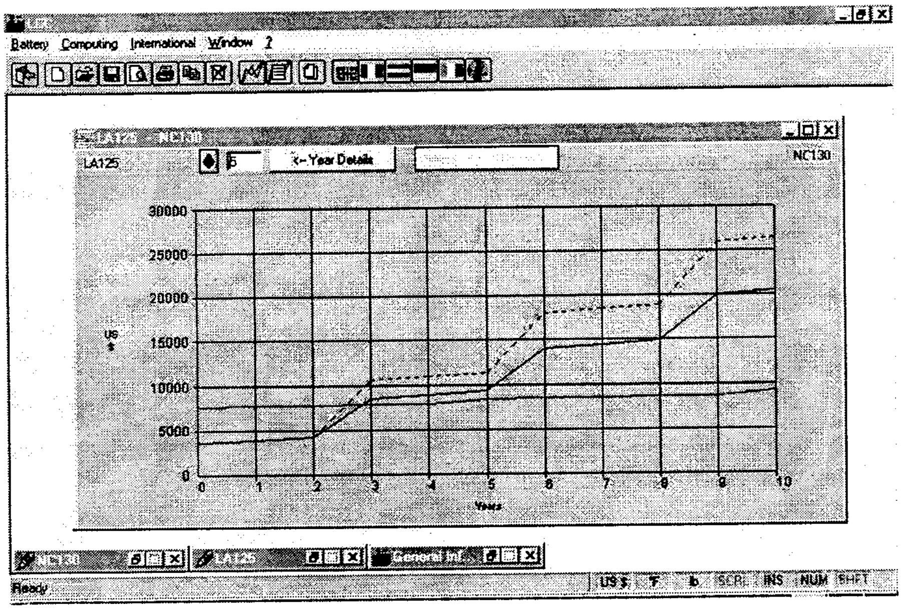

Figure 4: Line graph showing cost over a period of years

4.4 Graphs

It is possible to see the battery life cost analysis in a graphical form.

The general graph can display curves representing the cumulative battery cost, with and without downtime, and the cumulative exploitation cost for a maximum period of 30 years.
You can compare the cumulative cost for a defined period for two selected cell types.
If a downtime cost has been input then this will be shown as a dotted line, so that the added cost can be easily seen.

In the example shown it can be seen that, under the conditions defined (temperature 32°C/90°F), the nickel-cadmium battery, despite having a higher initial cost, becomes more cost effective than lead acid after 2 years.

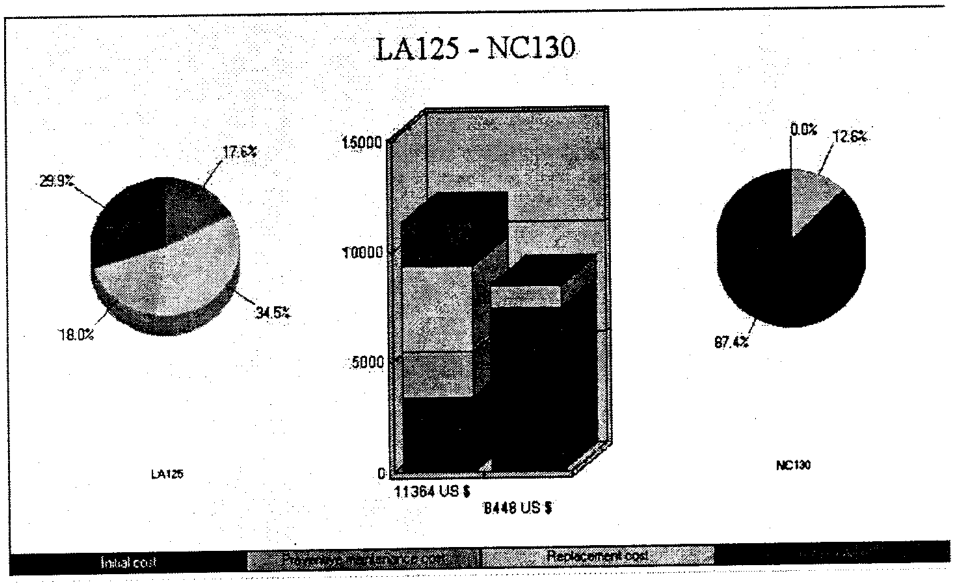

Figure 5: Bar graph showing costs for a particular year

With the second graph, which has both pie and bar graphs, for a specified year and the two chosen cell types, it is possible to compare the relation between the initial cost, the preventive maintenance cost, the replacement cost and the downtime cost. In the example shown, it can be seen that a large part of the lead acid cost is due to replacement of the batteries. This is not a factor with the nickel cadmium cell, so overcoming the higher initial installed cost of this technology.

5 CONCLUSIONS

This paper has presented the general factors on which a life cycle costing should be based and has outlined the details of the life cycle costing program, which has been developed by Saft.

The LCC program is entirely open in concept and will give a result that depends on the data that has been input and on the parameters that have been defined.

In the examples shown in the screen prints (Figures 1 to 5) the output shows a benefit from using a nickel-cadmium cell instead of a lead acid cell. This depends on the application and, in these cases, high ambient temperatures were involved. In other, less demanding, situations the opposite result could easily be found.

Life cycle costing is not the only factor which should be used in defining a battery choice but can prove a useful tool when making a decision.

For this reason Saft is making this program available to all interested parties.

6 REFERENCES

[1] IEEE Std 1188-1996 *Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications,*

[2] IEEE Std 450-1995 *Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications,*

[3] IEEE Std 1106-1995 *Recommended Practice for Installation, maintenance, testing and Replacement of Vented Nickel-Cadmium Batteries for stationary Applications.*