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AUTOMOTIVE LEAD/ACID BATTERY SERVICE-LIFE: MEASUREMENT AND SURVEYS

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Introduction

What is automotive battery service-life and what factors affect it? In the author's company, it is considered to be the median life, *i.e.*, the life when half the batteries made or sold in a given month have failed. Battery life is an emotive subject which is much discussed by manufacturers but which, in practice, is left somewhat to chance since the manufacturers often neglect to establish a monitoring system that will give the basic information required. This is surprising when it is understood that monitoring warranty claims and analysing failure modes are both important activities and sometimes are vital for the present and future prosperity of a given company.

Chloride conducts surveys of the data on the age of batteries in a given population and, providing the data are of a normal distribution, it has been found that by doubling the median age of the sample, the median battery life — that is the age to failure — will be found. For example, if the median age is 18 months then median life (*i.e.*, when 50% of the batteries have failed) will be 36 months. As in all statistical methods, the median-age figure will depend upon the size and representation of the sample. In order to arrive at a median figure in terms of the Chloride approach, it is, of course, necessary to collect data about manufacturing date, and to stamp this information onto the battery. Most manufacturers in Europe, America, Japan, and Australasia do this as part of their guarantee-claims checking system. Chloride operates in many different countries and the batteries perform under a wide range of climatic conditions. In recent years, the company has studied battery life in these countries and the following figures give a general indication of the findings.

U.K.

Median life:	35 months
90% life:	78 months, *i.e.*, 90% of batteries had failed at 78 months

U.S.A.

Southeastern States,	median life:	42 months
Southern States,	mean life:	29 months (Battery Council International (BCI) Survey, 1982)
Northern States,	mean life:	34 months

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It should be noted that the BCI survey was conducted at a time when maintenance-free battery technology was being introduced and this, and other factors, would have had an effect on the data.

Europe

Northern Europe,	median life:	36 months
Southern Europe,	median life:	30 months

Africa

Taking the African continent as a whole but excluding the Republic of South Africa, extensive experience indicates a median life of 15 months. This low figure is mainly due to the environmental factors and road conditions in force, but is also explained to some degree by the fact that the vehicle parks usually have a high truck population.

Japan

Chloride has no direct data on Japan, but battery life is expected to be similar to that of Northern Europe, *i.e.*, 36 months.

Australia

An Australian Lead Development Association (ALDA) survey held in Melbourne in 1981 gave a median life of 47 months. In 1985, a Chloride junk-yard survey held at the Sims Smelter in Sydney produced a similar median life.

Factors affecting battery life

Product quality and construction

Although clearly obvious, it bears repetition that if the quality of components, raw materials, and construction is not of the highest quality, then it will not be possible to manufacture a good-quality battery consistently. It is easy to make mistakes and accept the second best or the cheapest source of machinery, components, and materials; if this is done, however, then poor quality, indifferent life, and a bad reputation is the likely end-result. It is also true, unfortunately, that even with the best materials and parts, the same situation can apply if insufficient control of quality is exercised in the manufacturing and processing systems.

Efficiency and maintenance of the vehicle electrical system

There are differing views as to the effects on life of the various vehicle electrical components, *i.e.*, alternators, dynamos. However, if for some reason the charging system is incorrectly set, then battery life can be seriously affected. In some cases (*e.g.*, under-charging), the battery may fail to start the vehicle and be pronounced dead when in fact it may only require system adjustment and a recharge to bring it back to life.

It is probably true that alternators have improved battery life. Coincidentally, the use of alternators became widespread at a time when low-maintenance and maintenance-free batteries were also being introduced. In these systems, the reduced charge of around 14 V results in a lowering of the rate of battery decay due to over-charging. In fact, such batteries may never become fully charged during normal operation (see the paper by T. J. Taylor in this issue, pp. 157 - 174).

Battery location

Some vehicles have the reputation of prolonged battery life, *e.g.*, the British Mini and the German VW Beetle. In these cars, the batteries were located in the luggage compartment and beneath the rear seat, respectively. In both cases, the batteries were away from engine heat from the radiator or the exhaust manifold, as well as from possible sources of oil contamination which might have deterred owners from inspecting the electrolyte level.

Climate

Surveys and studies have shown that batteries generally will display longer lives in temperate climates than in climates with high or low ambients. This is not always the case, however, as revealed by the Chloride survey in Australia which produced significantly higher median lives than in the U.K. Compared with U.K. operations, this can possibly be explained by: absence of any low temperatures; lower population and vehicle densities; higher average journey distances; and possibly more economical driving techniques and characteristics.

At this point there is the obvious leading question: what is happening to battery life, is it increasing or decreasing? With the trend to smaller batteries and the increase in the power requirements of vehicles (*e.g.*, from electric windows, onboard computer systems, etc.), there is a strong argument to suggest that life should be decreasing. With improved electrical systems, greater component reliability, etc., there is also an argument for an increase in service life. From Chloride studies, life would seem to be fairly constant — with a slight trend towards a decrease.

Surveys

Three methods employed by Chloride to discover the median life of batteries are presented below as examples of surveying techniques. The procedures are neither complicated nor difficult. It is generally the not-inconsiderable work involved in finding, recording, and interpreting the data that presents the major problem.

Junk-yard survey

A junk-yard survey was conducted by Chloride at the Sims Smelter in Sydney, Australia in February, 1985. To achieve this, the smelter set aside its intake of scrap batteries. Upon receipt, the batteries were inspected and the following data were recorded: (i) make; (ii) battery type; (iii) manufacturing date; (iv) jar formation date; (v) date of receipt by distributor; (vi) selling date.

One assumption — that of failure date — had to be made and for this survey it was assumed that the batteries had all failed in December, 1984, *i.e.*, they had taken 1 - 2 months to travel through the scrap train. In the sample taken, the manufacturing date turned out to be the most commonly found date marked, so the life was based on this date. It is, of course, necessary to know how to decode the data. The codes used can normally be obtained from within the industry. It is important, however, that only coded batteries are used in the survey. An advantage of such a survey is that in addition to Chloride battery life, information is gained on competitors' products. It is also usually possible to determine the causes of failure as well as the ages of failure.

The results of the survey are presented as a histogram in Fig. 1 and, in the case of the Sims survey, they gave a median life of 53 months over the whole sample. In common with almost all surveys, the results from the Sims exercise should be taken with some caution. There are, of course, some inherent problems in a junk-yard survey, *e.g.*, non-representation of the sample and the probability that early failures had been removed from the scrap chain. Nevertheless, it was considered, in the circumstances, that the true mean life of the products was very similar to the ALDA survey of 1981 which gave a median life of 47 months over a larger sample (Fig. 1).

Chloride survey

A junk-yard survey, although giving one indication of battery life, does not, by its nature, take into account the batteries that have not yet failed. For this reason, Chloride has developed a further survey which measures how long batteries are lasting in service. Estimates of batteries manufactured and shipped out of the factory are not the same as batteries sold, or the number of batteries in use. What is known is the number of cars sold, so the Chloride approach is to go and ask the motorist.

In the U.K., it is easy to determine the year a car was sold by its registration plate. The car must also display a road-tax disc that gives the month of

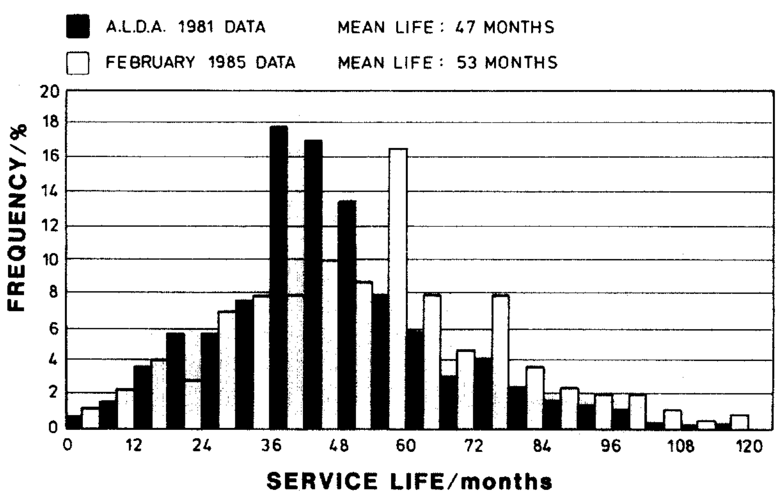

Fig. 1. Australian junk-yard survey of automotive lead/acid battery life.

purchase. This can be used to prompt the motorist to remember when he bought it and if he has replaced the battery. Chloride, therefore, obtains the number and date of failure for new batteries on cars, and also the numbers and ages of batteries that have not yet failed. The results of any form of survey depend on how representative the sample is. In Chloride's case, a number of check questions were asked against known national data and a representative place was found to carry out the survey.

The method of survey was for a team of researchers — in the Chloride case drawn from senior pupils at a local school — to interview motorists at random in car parks and town-centre locations. The results of the interviews were recorded on pre-printed forms divided into 2 sections: the first concerning the vehicle, and the second concerning the battery fitted to the vehicle.

Since it is unlikely that the motorist would remember accurately the date of purchase of the replacement before last, the battery life in the survey refers to Original Equipment life. For this, both the date of entry into service and the date of failure when the original was replaced are known.

The latest survey conducted by this method gave a median life of batteries of 35 months and this was generally in line with several previous surveys (Table 1).

TABLE 1
Results of Chloride survey of automotive lead/acid battery life: (a) median life is 35 months, in keeping with data from previous surveys shown in (b).

(a) Battery life

Time to failure (months)	Number	Cumulative %
0 - 6	3	3.2
7 - 12	8	11.6
13 - 18	9	21.1
19 - 24	5	26.3
25 - 30	14	41.4
31 - 36	9	50.5
37 - 42	12	63.2
43 - 48	3	66.3
49 - 54	7	73.7
55 - 60	5	78.9
61 - 72	8	87.4
73 - 84	5	92.6
85 - 96	4	96.8
97 - 108	3	100.0

(b)

	1984	1983	1982	1981	1980	1979
Median	35 Mths	37.5 Mths	42.5 Mths	36 Mths	42 Mths	42 Mths
95% confidence level	30 - 40	33 - 42	37.5 - 48	30 - 41	36 - 49	N/A

TABLE 2

Survey of ages of automotive lead/acid batteries

Age (months)	Number	%	Cumulative %
0 - 6	432	30.7	30.7
7 - 12	254	18.0	48.7
13 - 18	231	16.4	65.1
19 - 24	101	7.2	72.2
25 - 30	117	8.3	80.6
31 - 36	83	5.9	86.4
37 - 42	60	4.3	90.7
43 - 48	43	3.1	93.8
49 - 54	28	2.0	95.7
55 - 60	25	1.8	97.5
61 - 72	20	1.4	98.9
73 - 84	9	0.6	99.6
85 - 96	5	0.4	99.9
97 - 108	0	0	99.9
109+	1	0.1	100.0

Warranty-claim survey

Another factor of interest was the ages of batteries, *i.e.*, on the day of the survey, the period during which people had had their batteries (Table 2). There is a further method in use at Chloride to estimate median life, and this

Month	No. Made	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Tot.
Jan	10000	0 / 0	12 / 0.12	20 / 0.32	50 / 0.82	70 / 1.52	90 / 2.42	100 / 3.42	80 / 4.22	100 / 5.22	150 / 6.72										
Feb	8000	0 / 0	8 / 0.10	15 / 0.29	40 / 0.79	50 / 1.41	80 / 2.41	80 / 3.41	60 / 4.16	80 / 5.16											
Mar	5000	0 / 0	6 / 0.12	12 / 0.36	13 / 0.62	15 / 0.92	20 / 1.32	30 / 1.92	36 / 2.64												
Apr	7000	1 / 0.01	5 / 0.9	6 / 0.17	9 / 0.30	7 / 0.40	10 / 0.54	15 / 0.76													
May	6000	1 / 0.02	3 / 0.07	5 / 0.13	10 / 0.32	9 / 0.47	10 / 0.63														
Jun	8000	1 / 0.01	3 / 0.05	4 / 0.10	7 / 0.19	12 / 0.34															
Jul	12000	4 / 0.03	4 / 0.12	10 / 0.28	20 / 0.49																
Aug	6000	17 / 0.28	35 / 0.87	45 / 1.62																	
Sep	9000	5 / 0.06	15 / 0.22																		
Oct	12000	10 / 0.08																			
Nov																					
Dec																					
Jan																					
Feb																					
Mar																					
Apr																					
May																					
Jun																					

NUMBER FAILED IN THAT MONTH OF SERVICE

90 / 2.05

CUMULATIVE PERCENTAGE FAILED.

Fig. 2. Warranty returns for automotive lead/acid batteries: months in service by month of manufacture.

involves monitoring warranty claims. This, of course, is a very important factor in deciding what a company's warranty will be for a particular product. In the case of automotive batteries (including maintenance-free and low-maintenance types), since they are mature, established products with more or less stable sales patterns, the life statistics (or failure rate) will conform to a family of statistical distributions called the Weibull Distribution.

In this method, the vital part is to ensure that every battery is date stamped and that the warranty return system records the date of manufacture. In practice, the cumulative percent. return is plotted on Weibull paper and from the distribution curve, the 50% return, which is the mean age of failure, can be estimated.

An additional advantage of the Weibull technique is that it can give advance warning of problems. To do this, the figures are entered on a chart and a triangular grid is built up (Fig. 2). If, in any month, there is a significant difference in the cumulative percentage of failures, then this will signal likely problems, as well as giving the precise month of manufacture, to enable their causes to be investigated.

On the Weibull graph, the slope of the curve β also indicates if the product is in a decreasing failure mode, an increasing failure mode, or a random

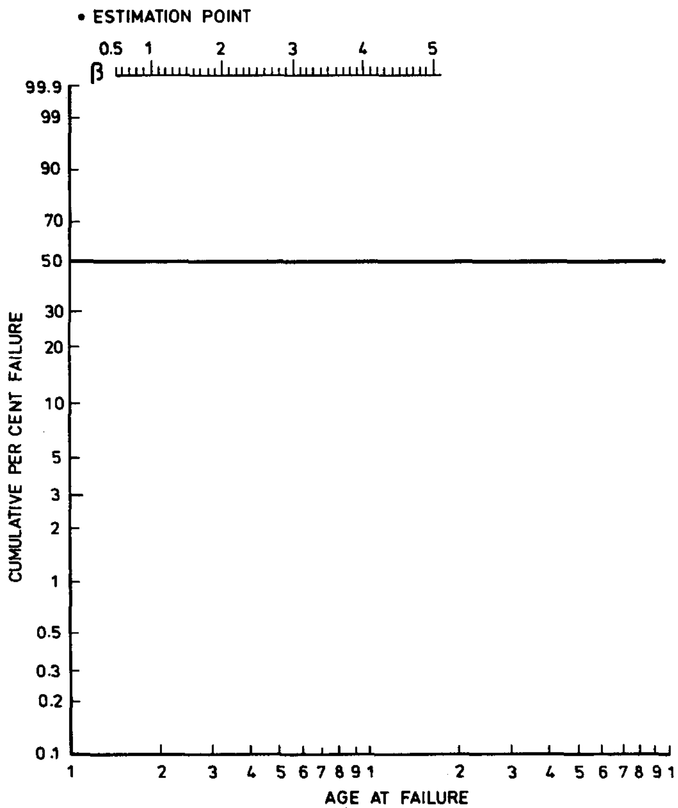

Fig. 3. Weibull graph.

failure mode. This is done by joining the estimation point to the curve to cross it at right angles (Fig. 3). If the line crosses the β line where $\beta < 1$, then the failure mode is decreasing. If $\beta > 1$, then the failure mode is increasing. If $\beta = 1$ the failure mode is random. Again, this provides the opportunity of referral to the month of manufacture to investigate the reasons for failure. Because of the problems of finding the slope, particularly on logarithmic graph paper, Chloride uses a computer programme to assess the most likely slope, given the data input, and thus to predict the mean failure rate.

Conclusions

The methods outlined above may seem to be needlessly complicated at first glance, but if accurate battery-life data and life estimation are important for guarantee purposes or for production purposes, then analyses are necessary. Division of the number of batteries sold in the country by the number of vehicles is not sufficient to arrive at a battery life. The alternative methods proposed involve considerable work in collecting data but the end-result is sufficiently accurate to be used with confidence.