QUALITY TEST OF LEAD ACCUMULATORS, ESPECIALLY OF MAINTENANCE-FREE, SEALED LEAD BATTERIES WITH IMMOBILIZED ELECTROLYTE

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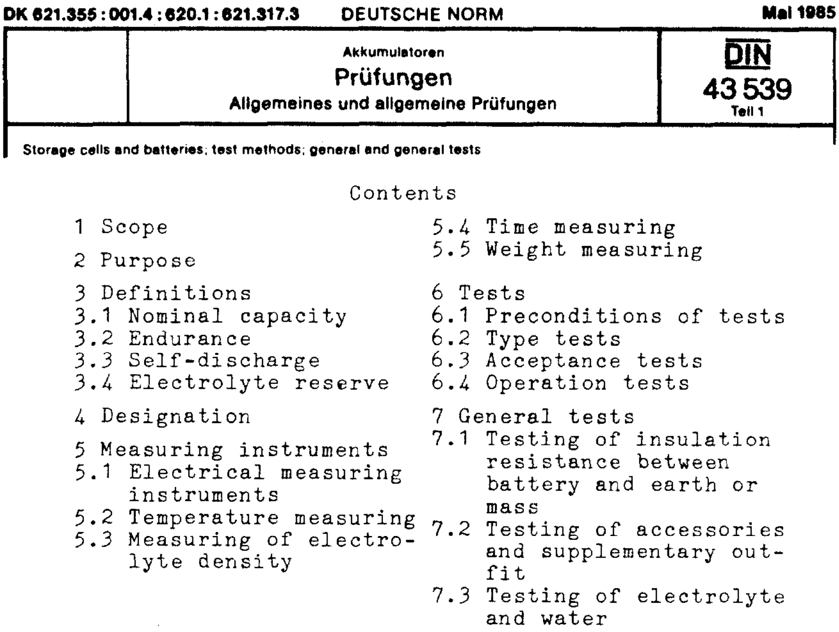
Prior to testing a battery, the question arises as to whether regulations exist in this respect or whether there are general standards to be applied. In Germany, the standard DIN 43 539, Part 1, contains the generalities and common tests for accumulators. Figure 1 shows the title, and the contents of the standard divided into 7 principal parts. The scope indicates that the Standard is valid for all types of accumulators, and lays down definitions and general tests for accumulators — the type test, the acceptance test, and tests during operation, *i.e.*, 3 different test procedures.



DK 621.355 : 001.4 : 620.1 : 621.317.3 DEUTSCHE NORM Mai 1985

Akkumulatoren
Prüfungen
Allgemeines und allgemeine Prüfungen

DIN
43 539
Teil 1

Storage cells and batteries; test methods; general and general tests

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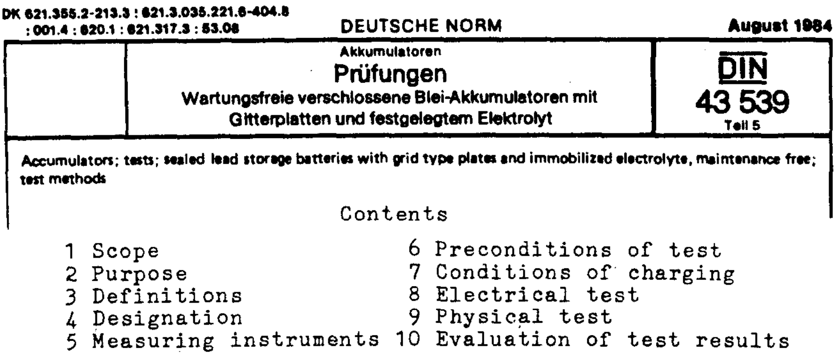
Fig. 1. DIN 43 539 Part 1.

On studying the definitions, the reader will realise that the standard cannot be used alone since, within its separate parts, it refers to at least 25 other standards which contain detailed specifications. The tester will only obtain limited information from the section dealing with measuring instruments — giving the accuracy required. The section dealing with tests explains preconditions concerning the batteries to be tested and defines the type, acceptance and operation tests. Again, however, reference is made to other standards which contain the necessary detailed information.

More assistance is available from the special test standard for the maintenance-free, sealed lead accumulators with grid plates and immobilized electrolyte. This is DIN 43 539, Part 5, the title and contents of which are shown in Fig. 2. In this standard, too, reference is made to 7 further standard sheets containing information without which the tests cannot be carried out according to the regulations. It describes in detail, however, how the batteries must be charged, which test groups must be used for which capacity test, and how to deal with endurance after cycling, self-discharge, deep-discharge, and an additional physical test. Furthermore, it stipulates the minimum test results necessary to meet the quality requirements of an existing product standard for this kind of battery.



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DEUTSCHE NORM

August 1984

Akkumulatoren
Prüfungen
Wartungsfreie verschlossene Blei-Akkumulatoren mit
Gitterplatten und festgelegtem Elektrolyt

DIN
43 539
Teil 5

Accumulators; tests; sealed lead storage batteries with grid type plates and immobilized electrolyte, maintenance free; test methods

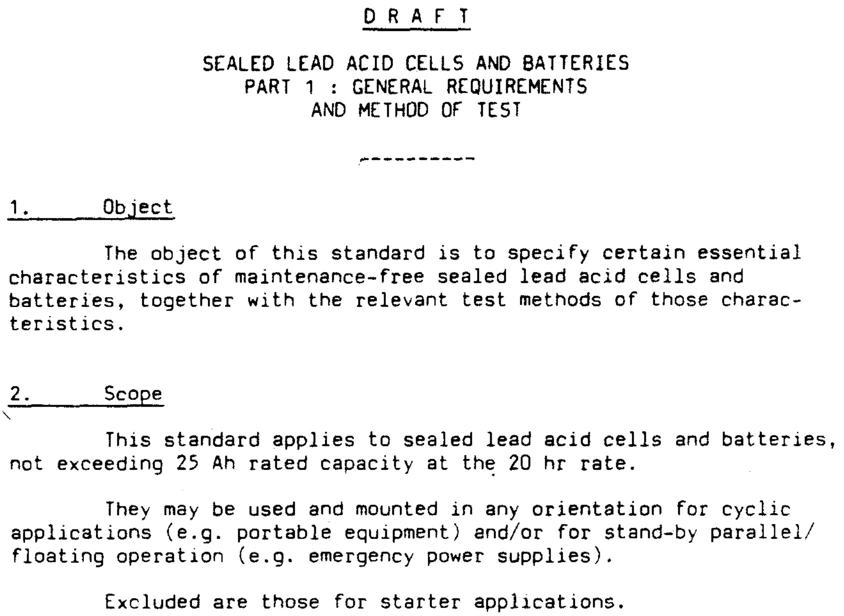
Contents

1 Scope
2 Purpose
3 Definitions
4 Designation
5 Measuring instruments
6 Preconditions of test
7 Conditions of charging
8 Electrical test
9 Physical test
10 Evaluation of test results

Fig. 2. DIN 43 539 Part 5.

Finally, it lays down that batteries must yield 100% of their nominal capacity by the 3rd charge/discharge cycle, that their self-discharge must not be more than 0.125% per day, that their endurance must be at least 200 charge/discharge cycles, and that their capacity decrease must not be more than 25% after 30 days storage in a deep-discharged condition, followed by recharging.

An international IEC standard for maintenance-free, sealed lead batteries with immobilized electrolyte, whose title, object, and scope are shown in Fig. 3, will be available shortly. The larger part of this standard consists of the methods of test which, being much more comprehensive than those in the German standard, describe and determine the test procedures. In addition to the German regulations, it stipulates the maximum load, the



D R A F T

SEALED LEAD ACID CELLS AND BATTERIES
PART 1 : GENERAL REQUIREMENTS
AND METHOD OF TEST

1. Object

The object of this standard is to specify certain essential characteristics of maintenance-free sealed lead acid cells and batteries, together with the relevant test methods of those characteristics.

2. Scope

This standard applies to sealed lead acid cells and batteries, not exceeding 25 Ah rated capacity at the 20 hr rate.

They may be used and mounted in any orientation for cyclic applications (e.g. portable equipment) and/or for stand-by parallel/floating operation (e.g. emergency power supplies).

Excluded are those for starter applications.

Fig. 3. International IEC-Standard.

behaviour after longer storage periods and the tightness of the batteries to be tested, giving exact valuation figures. In this case, too, there is no test procedure to provide a clear picture of the service life to be expected under floating operation. This is especially unfortunate, since by far the greater number of batteries of this type are used under constant voltage charging conditions.

Unfortunately, even today, no universally accepted and really informative test procedure has been developed which will allow such a test to be carried out within a reasonably short period of time. If made at all, the test is carried out at elevated ambient temperatures over a period of weeks or months, but a clear relation between the service life at elevated ambient temperatures and the service life to be expected at normal temperatures could never be found, and may not even be generally valid. There are certain empirical data suggesting the degree to which the service life of sealed lead batteries is reduced at elevated ambient temperatures. These data, however, are merely based on statistics. In 1984, for example, the Japanese Battery Association published a graph which is represented in Fig. 4. The different slope of the curves between stationary and small sealed batteries cannot be explained. Sonnenschein uses the dependence according to Fig. 5 giving the daily remaining loss of capacity at different temperatures. It is used more as a statistically supported warning of battery application at excess temperatures.

It is essential that the user of a battery in stand-by/parallel operation for uninterrupted power supply to an important consumer be familiar with

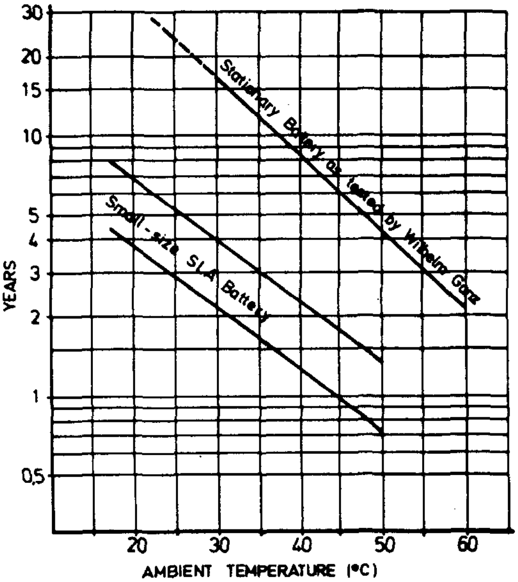


Fig. 4. Representation by the Japanese Battery Association of the influence of temperature on the service life of lead batteries.

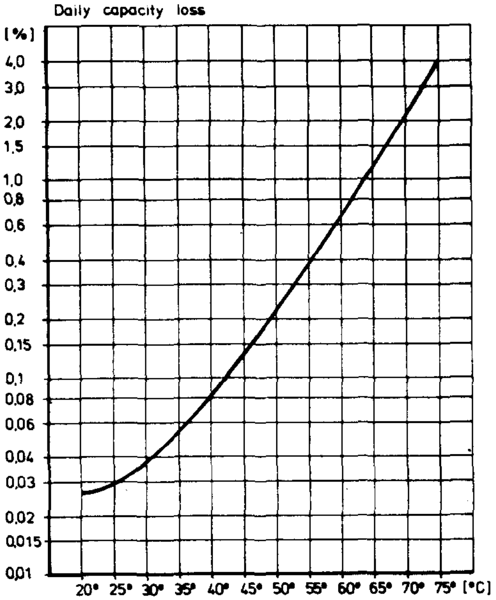


Fig. 5. Influence of temperature on permanent loss of capacity during continuous charging of small, sealed lead batteries.

the quality of the battery over the operating period, and know the exact time when the quality deteriorates and the battery must be replaced in order to prevent equipment failure.

In the German patent DE 2812874 C 2, applied for on 23.03.1978 and granted on 07.02.1985, a device is described which clearly and satisfactorily solves the above problem. It works according to the following principle: power pack, battery, and consumer are continuously connected in parallel. The power pack, directly or via a suitable converter, supplies the continuous charging voltage specified for the battery which, at the same time, represents the operating voltage of the consumer. As long as mains voltage is available, the consumer is supplied and the battery, from the voltage offered, takes the current it requires for charge retention or, in the case of previous discharge, for recharging. In addition, an electronic device is connected to these circuits which continuously, at very short time intervals, disconnects the battery from the power pack, at the same time emitting a discharge pulse to the battery whose current normally corresponds to the maximum current required by the consumer. The voltage rate adjustment in the battery under the influence of the pulse is measured and recorded until the next measurement is taken. A voltage rate difference produced between a minimum given voltage rate still sufficient for supplying the consumer and the higher voltage rate adjustment in the battery under the discharge pulse is continuously indicated until the next measurement is taken. Over the service life of the battery this difference voltage rate normally only increases slowly by activating the battery, and slowly decreases to zero during subsequent years. As shown by the voltage gradient in Fig. 6, this continuously indicated difference voltage rate may be considered as a quality scale for the battery. Its maximum rate may be considered as 100% quality, whereas the zero difference voltage rate may be considered as the end of quality. The observer

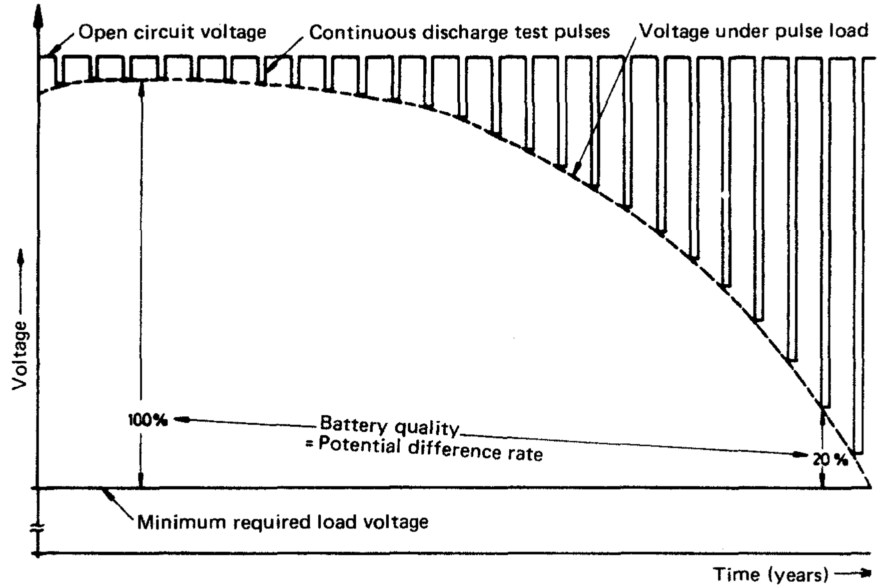


Fig. 6. Voltage diagram of continuous quality test by cyclic discharge pulses.

of such equipment may judge from the slowly decreasing difference voltage or quality rate the exact time when the battery may be expected to fail and, therefore, must be replaced.

An electronic data acquisition and processing computer has been successfully introduced and approved in testing for the continuous control of production quality. It is also used in the development field for the examination of sample cells and batteries and for the investigation of competitive products.

About 20 years ago, the minicomputer entered the field of general equipment control, and about 5 years later, the first individually designed battery testing systems were computer controlled. A typical configuration consisted of the central computer with teletype for data input and output and intersections for controlling the test circuits and detecting the analogous potentials. Due to the small storage capacity of 16 K max. at that time, in

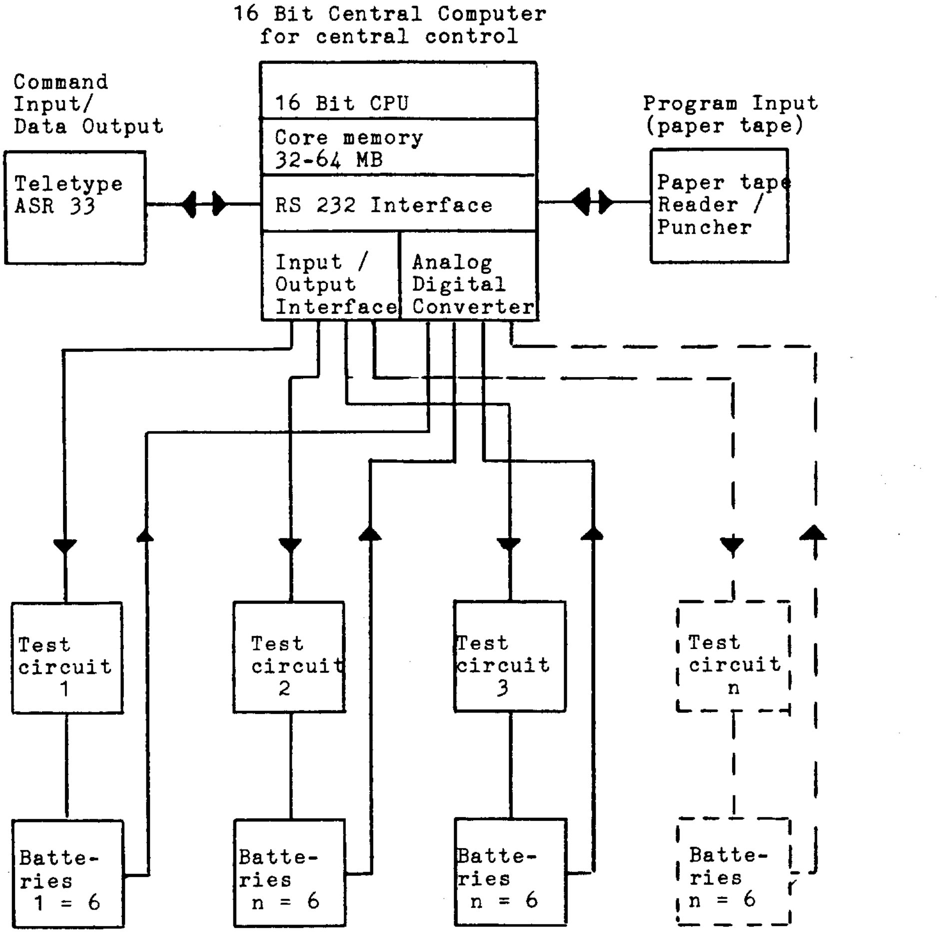


Fig. 7. Centrally controlled test system of the 1st generation with immediate data output.

most cases the test results were printed immediately. The programs were recorded on paper tape and fed into the computer by a reader. Figure 7 represents a computer-controlled battery testing system of this first generation.

The subsequent generation is more convenient. Data input and output are now made by means of video and printer. Diagrams are now issued by plotters. Based on advanced memory technology, the storage capacity of the main memory unit of the computer is increased so that more convenient programs can be realized. Furthermore, additional external memories (disk mechanisms) are available, allowing the recording and processing of data for statistical purposes. Programs are now recorded on diskets or disks and are fed into the computer via disket or disk mechanisms whenever required.

All test procedures and data acquisition are centrally controlled by the computer. The test circuits and test positions are switched on and off via adequate interfaces; interim control of the battery potentials is made via analog digital converter intersections, and the test results are temporarily stored for eventual printing of test certificates. At the end of each charge/discharge test procedure, the test results are issued as test certificates or diagrams.

With this centrally controlled configuration only a limited number of programs can be run at the same time. Further, hardware failures are always likely to occur which will affect the whole system. For bigger and more complex systems which are run in real-time operation, the long-term data plotting and recording are only possible in separate systems. Figure 8 represents the second generation system.

A considerable reduction of hardware expenditure has been achieved in recent years due to the advancement in the field of hardware, so that more intelligence can be placed on site. Microprocessor technology allowed the reduction of unit sizes which, together with the cost reduction, enabled the construction of satellite systems which, in the future, are likely to replace the centrally controlled systems.

In the satellite construction, each test circuit has its own 16 bit computer which is connected to the central computer (16/32 bit) via a standard intersection. Complete programs are fed from the central computer into the satellite computers and are autonomously performed within the test circuits. The data communication is thereby reduced to the feeding of programs and the complete delivery of test results from the satellite to the central computer, which can also take over more complex statistical data processing, as well as the issue of diagrams and test certificates. At the same time, it can be used for recording long-term analysis so that all tasks — acquisition of test data and procedure control on the one hand, and recording and plotting on the other — can be performed within one system.

Due to the satellite construction, a real multiprogram can be carried out which is only limited by the maximum number of autonomously working satellites to be connected. Figure 9 explains the aspired concept of a third generation battery testing system.

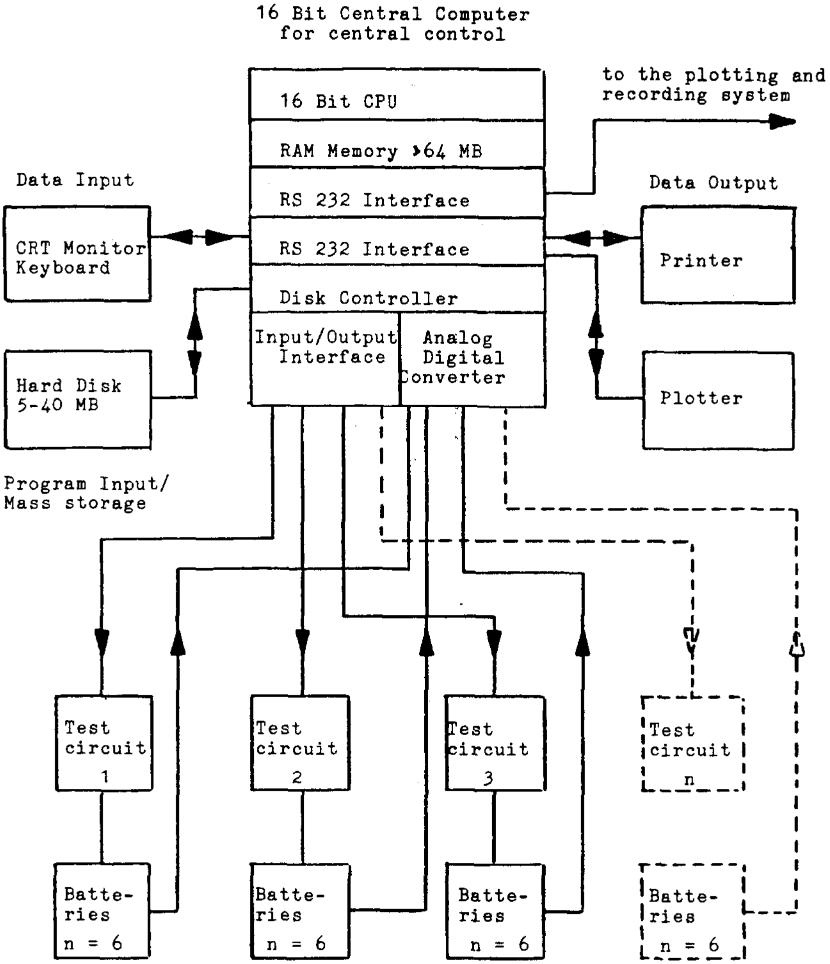


Fig. 8. Centrally controlled 2nd generation test system with partial analysis of test results, long-term analysis, and external recording.

A statistical analysis of sealed lead batteries of the type Dryfit A 200 based on the production control data is shown in Fig. 10. It represents the capacity ranges of these batteries in a cycle test, giving the minimum and maximum marginal numbers of four specific quality groups. The batteries are considered dead when their nominal capacity, rated 100%, has decreased to 60% during the cycle test. From left to right, and from bottom to top, 4 quality ranges related to the capacity behaviour can be seen. The smallest range on the left covers the capacity of 2% of all batteries tested which have failed within 5 cycles. These batteries have typical congenital defects, mostly mechanical faults caused during production, *e.g.*, major or minor short-circuits due to defective separators. The second range, also covering a volume of 2% of tested batteries, contains those batteries which have reached the end of their service life after 5 - 250 charge/discharge cycles. This is also due

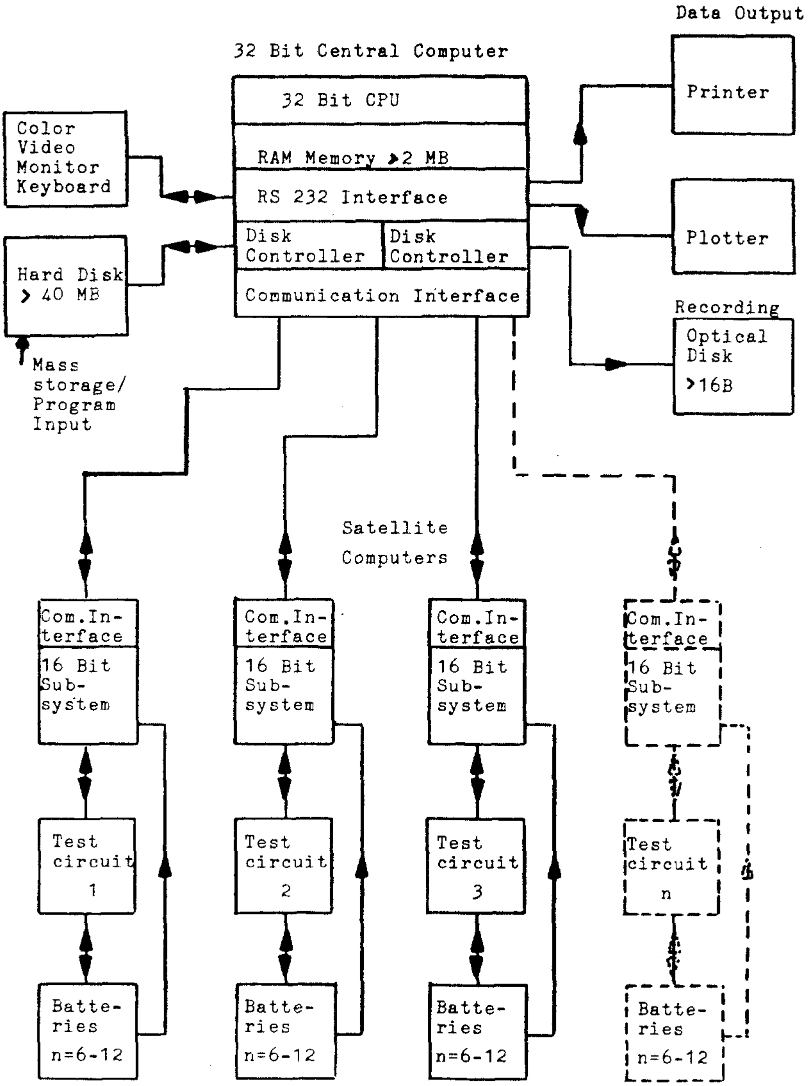


Fig. 9. Third generation test system as a satellite system with integrated analysis and recording.

to production or material defects, mainly porosities of the housing material, *e.g.*, flow welds or cover weldings, but also defective valves, shrink holes in the terminal ducts or poor plate soldering during group production.

The third range involving 95% of all batteries tested covers a service life of 250 - 500 cycles. The greater part of all batteries tested, however, had a cycle stability of between 250 and 350 cycles.

The final range of 1% covers batteries with an extremely long cycle life. Unfortunately, there is no absolute explanation for this extremely good behaviour. With these batteries, everything is correct and no inhomogeneities or measurable tolerances can be found.

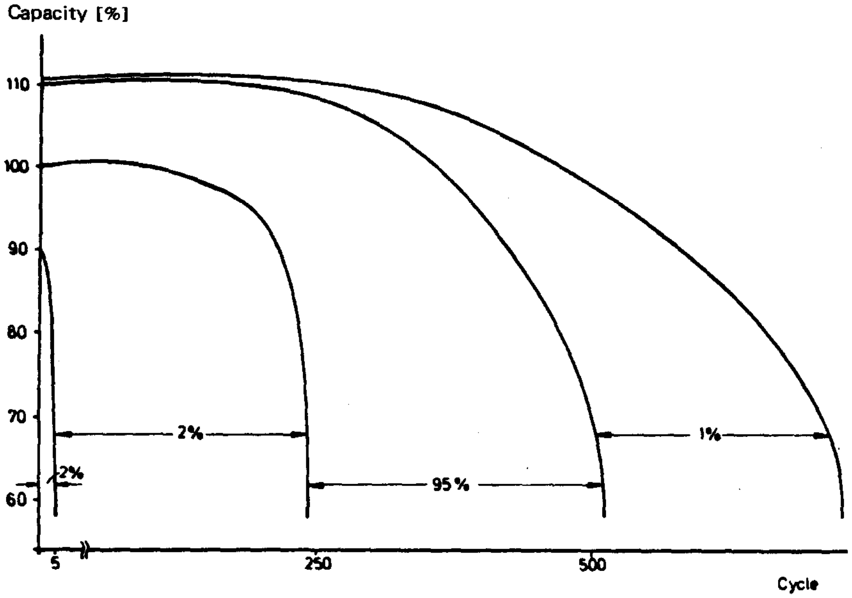


Fig. 10. Statistical analysis of the cycle stability of Dryfit A 200 directly connected to production for the purpose of eliminating faulty items.

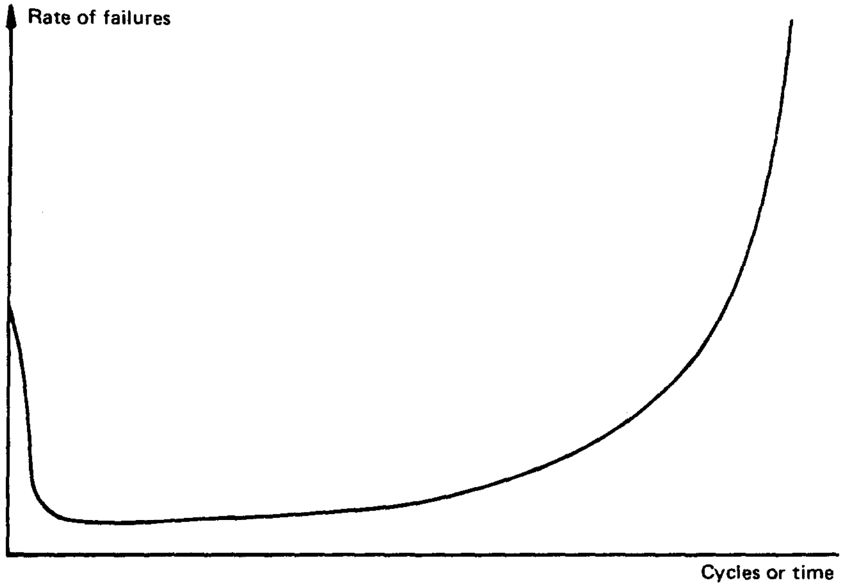


Fig. 11. A bath-tub curve; typical failure behaviour over cycles or time.

Based on this extensive field test experience, and as a result of the failure range of maintenance-free, sealed lead batteries with grid plates and immobilized electrolyte of the Dryfit A 200 series type, a bath-tub type curve representing cycle stability is shown in Fig. 11. During the first 5 cycles, the 2% failure portion is relatively high, *i.e.*, it includes all batteries with plainly congenital defects. Consequently, some test discharges must be made before the batteries leave the factory in order to ensure that such defective batteries are singled out. During the tests up to 250 cycles, the failures decrease to a very small number which, as cycling continues, increases, first slowly and then very steeply.

A similar curve could be drawn for the failures of such batteries which are used under float charging in stand-by/parallel operation. In this case, however, no bath-tub curve has been drawn. Only the following failure percentage rates, accumulated yearly, and based on extensive experience gathered from practical operations worldwide, in different float applications and from endurance tests in their own test fields, are mentioned, producing the following picture:

Accumulated failure portion of maintenance-free, sealed, Dryfit A 300 lead batteries with grid plates, under float charging in:

year 1 — approx. 1.00%
year 2 — approx. 0.75%
year 3 — approx. 1.00%
year 4 — approx. 2.25%
year 5 — approx. 7.00%

Finally, it must be stressed that the rates mentioned only apply to small maintenance-free, sealed lead batteries with grid plates and immobilized electrolyte of up to 25 A h, the type series Dryfit A 200, and not to Dryfit Block batteries developed therefrom of 12.5 - 200 A h with a service life of 8 - 10 years, nor to the big Dryfit batteries with armoured plates and a service life of 12 years and more. Also excluded from this summary is, of course, the new type series Dryfit Longlife, whose service life under float charging is also twice as long.

Bibliography

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