Development of Reliability Engineering in China

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Abstract: The Status quo of the reliability in China is described in this paper, a reliability surge is now spreading in China, covering the fields such as hardware, software, machinery and electronics.The reliability work in China was firstly conducted by the CEPREI Lab as far as early in the 1950s, and the reliability engineering in China has developed from the reliability of electronic products to that of machinery and non-electronic products, from hardware reliability to software reliability, from the attention to the reliability statistical test to emphasis on the reliability engineering test. Concern of Chinese companies about the reliability is the complete import of reliability engineering , the reliability testing, the software reliability and the reliability of lead-free soldering. Demonstration of reliability cases is given.

1. Status quo of the reliability in China

1.1 Quality concept oriented with the reliability is now taking shape.

With the introduction of the new quality concept represented by ISO 9000-2000 System, people get more and more conscious of the reliability. Reliability is widely regarded as the quality index in terms of the time and is the time attribute of the product quality and the influence of such attribute over the customer satisfaction is more significant than that of the quality inspection.

For instance, when defining the warranty period for one electronic energy meter, the concept of reliability could then be used, namely:

$$R = e^{-\lambda t}$$

Wherein, the "R" represents the reliability and then the "1-R" represents the unreliability; in this case, we can understand it as the repair rate in the time 0-t, which is very important for us to determine the return-to-repair period.

1.2 Requirement for quantitative reliability index is drawing more and more attention.

As requested by customers, requirements for quantitative reliability index are becoming more and more. In the reliability prediction and test, the reliability indexes mostly used are MTBF(Mean Time Between Failures), MTTF(Mean Time To Failure)and R(Reliability) and the types of lifetime distributions typically used are exponential distribution and Weibull distribution, while in the applications of the electronic products, the former takes the majority.

1.3 Reliability system analysis techniques are widely employed.

In order to ensure the reliability at the design stage, the reliability system analysis techniques are widely used, for example, the reliability modeling, reliability prediction, FMEA/FMECA (failure mode and effect analysis), FTA(fault tree analysis) and SCA(sneak circuit analysis), among them, the first three are more widely used due to their simplicity and practicality.

1.4 Quality and reliability control of the components draws a close attention.

At present, one of means to control the quality and reliability of the components is to manage the purchase and use of the components, such as compilation and application of the PPL(Preferred Products List); another means is through the micro-physics analysis for the components, for instance, using DPA（destructive physical analysis） to identify the quality of components and optimize the production technology, and using failure analysis(FA) to find the reasons of the failure and provide the micro-evidence to improve the products. Over the past ten years, DPA and FA have all played the great roles

in the product reliability growth.

1.5 Software reliability draws a close attention.

Due to the fact that quantities of desktop software and embedded software are extensively applied to diversified products, the quality and reliability of the software is getting more and more influence over the product quality; at present, one of major methods to control the quality is to develop the software with the software engineering, implement the CMM (Capability Maturity Model) certification for the software as well as the testing the software by the third party.

1.6 Reliability tests are widely used.

At present, reliability tests mainly include the reliability determination test, reliability qualification test and reliability acceptance test, which are collectively called as the reliability statistical test. The environmental stress used by the reliability test has developed from the conventional combined environmental stress to the currently extensively-used integrated environmental stress. Reliability screening test and reliability growth test are collectively called as the engineering test and are now widely employed. National standards for the accelerated life test of the components were promulgated and put into operation twenty years ago, while such test for the equipment has also been employed by enterprises gradually in recent years.

1.7 Environmental adaptability test and its research have been extensively conducted.

In order to examine the environmental adaptability of the products, total 13 environmental tests such as high temperature, low temperature, temperature shock, vibration and salt fog test are performed. Depending on the category of the products, the quantities of items used are therefore different, however they remain the test items which must be conducted before the delivery of the products to the user. In the design of the product, the environmental control technology is used so as to relieve the environmental influence over the equipment including the cooling facilities and shock absorbers; while the environmental protection control techniques such as the

sealing design, organic or inorganic covering are used so as to improve the environmental adaptability of the original materials, structure, parts and components.

1.8 Reliability design gradually draws the public attention.

The reliability design is the key to ensure the reliability of the product; the product design must go through the necessary reliability design procedure based on the characteristics and application environment of the product. Typically used techniques in reliability design include the derating design, reinforcing design, tolerance analysis, drift design, redundancy design, sneak circuit analysis, electronic product thermal design, electrical-over-stress protection design, EMC design and ESD protection.

1.9 Reliability education and training comes to a new climax.

With the expansion of the international cooperation, the demand for the reliability is ever increasing and the technical personnel in enterprises are now in urgent need of knowledge concerning the RMS (reliability, maintainability and supportability), which in turn produces lots of reliability training demand; the training service organizations are diversified, including the professional ones sponsored by the government and associates, and also the consultation agency.

1.10 Computer-aided reliability software has been developed.

Based on the actual conditions of the application of reliability, maintainability and supportability engineering in China and according to the RMS standards as well as the method of design analysis, China has developed the engineering application software – Reliability & Maintainability Engineering Application Software-CARMES-2000, which integrates the reliability modeling, prediction, distribution, analysis, design and management as a whole. CARMES-2000 consists of several modules including reliability prediction, FMEA, FTA, FRACAS, hazard analysis, maintainability analysis and supportability analysis.

In short, a reliability surge is now spreading in China, which is different from the previous ones. The striking features lie in focus on the

civilian-use products, the orientation with the customer demand (international) and the attention paid to the practicality and quantitative analysis, covering the fields such as hardware, software, machinery and electronics.

2. Reliability development in China

The reliability work in China was firstly conducted by the Fifth Research Institute of Ministry of Electronic Industry, the former CEPREI Lab. As far as early in the 1950s, China has constructed its sub-tropical environmental adaptability testing base in Guangzhou with the engagement in the environmental testing of electronic products and the study on tropical protection measures; over the first more than ten years, the natural exposure test always took the lead and a great deal of test samples have gone through the exposure test.

During this period, we introduced the reliability research findings abroad achieved by the USA and the former Soviet Union, making the first step on the way of the reliability technology research in China. Afterwards, some periodicals such as Reliability & Environmental Testing Evaluation and the Overseas Radio Appliances Reliability and Environmental Testing were issued periodically. In 1964, a national-wide reliability training class was held, which cultivated the first batch of technical personnel and experts on reliability for us.

In 1970s, the electronic component screening study was performed for the space products and the "Seven Professional" products were developed, which decreased the failure rate of the component to approximately one order of magnitude and guaranteed the need to develop the aerospace flight vehicles. The reliability certification test on the components and the accelerated life test were both conducted, which promoted the development of the reliability test and data analysis study.

Owing to the intensive requirement of the consumers, since the year 1978, the former State Planning Commission, the Ministry of Electronic Industry and the State Administration of Radio and Television Industry have successively

convened the work conferences concerning the improvement of the television quality and have clearly put forward the reliability and safety requirements and reliability indexes for television sets and other products, and have further organized the equipment and components producers around the country to implement the large-scale comprehensive quality management focusing on the reliability. In the period of five years, the MTBF of the television was increased by one order of magnitude.

Since the mid-1980s, the requirement of the reliability and maintainability was put forward with the design and manufacture of some aerospace equipment and large systems; researches concerning the reliability distribution and prediction, FMEA, failure tree analysis, reliability test and data analysis have been carried out, which promoted the development of the reliability engineering.

During this period, the government formulated the basic standards on reliability and maintainability, thus a relatively well-organized reliability and maintainability system was established. In particular in 1986 and 1988, the first reliability prediction manual "Reliability Prediction Handbook for Electronic Equipment " and "Non-operation Reliability Prediction Handbook for Electronic Equipment" in China was promulgated, indicating that our reliability evaluation has scaled from the qualitative stage to the quantitative stage and has provided the support for reliability indexes for our quantitative predication and analysis of electronic equipment at the work, storage and resting state.

Since the 1980s, mechanical reliability study has drawn the attention in China. As from the year 1986, the Machinery Industry has formulated six lists on which the reliability of mechanical and electrical products must be examined within the specified time limit, On November 1990 and October 1995, the Machinery Industry convened two press conferences and had respectively introduced to the public a lots of kinds of mechanical and electrical products with the reliability indexes for national generalization.

Reliability engineering in China has developed from the reliability of electronic products to that of machinery and non-electronic products, from

hardware reliability to software reliability, from the attention to the reliability statistical test to emphasis on the reliability engineering test with the environmental stress screening and reliability reinforcing test to expose the product failure so as to improve the product reliability, and evolved from the reliability engineering into a multi-subject discipline including the maintainability engineering, testability and supportability engineering.

3. Reliability academic organizations in China

In order to ensure the reliability and maintainability research, design, test and management be carried out and to enhance the academic exchange, in 1979, the Chinese Institute of Electronics established the Electronic Product Reliability and Quality Management Institute, namely, the current Reliability Society of Chinese Institute of Electronics, which is the first society of its kind on reliability in China. And in September 1981, the Society convened the first academic annual meeting in Guangzhou, which is convened once every two years, and the Thirteenth will be held in October of this year. The National Reliability Physics Colloquium and the Electronic Product Protection Technology Colloquium are both convened by the Reliability Society of Chinese Institute of Electronics once every two years.

Periodical on reliability which is the earliest and most influential is the Electronic Product Reliability and Environmental Testing; it is sponsored by the CEPREI Lab and cooperated by the Reliability Society of Chinese Institute of Electronics. It was established in 1962 and issued both at home and abroad. This Periodical proves to be the most authoritative scientific and technological periodicals on reliability academics and techniques with an extensive coverage, covering several industries and sectors such as the electronics, aviation, space, ship building, railway and education; it has made a great contribution to the reliability improvement of our electronic products.

China's International Conference on Reliability Maintainability & Safety (ICRMS) is the top-level RMS academic conference in China. Its aim is to study and exchange the latest RMS development in the world, enhance mutual

understanding and friendship between China and international RMS experts and scholars and further mutually promote the prosperity and progress of international RMS studies so as to create benefit for the mankind.

Besides above, China has also established, in a successive manner, other professional technological organizations such as the Electric Product Reliability & Quality Management Committee of the Chinese Institute of Electronics, the Reliability Committee of the Chinese Mechanical & Electrical Engineering Society, Maintainability Engineering Committee of the Chinese Society of Aeronautics and Astronautics, Reliability Committee of the Chinese Society of Aeronautics and Astronautics.

4. Work conducted by China CEPREI Lab in the filed of reliability

China CEPREI Lab, also called China Electronic Product Reliability and Environmental Testing Research Institute, was established in 1955 and is the first authoritative organization in the reliability study in China. It is located in Guangzhou- a city in South China. In CEPREI Lab, business departments relevant with the reliability respectively are reliability engineering testing center, reliability environmental testing center, electronic product failure analysis center, reliability data center, safety & electromagnetic compatibility center, certification center and the reliability testing equipment manufacturing company.

China Electronic Components Certification Board – the first quality certification organization in China – was established in April 1984 and in April 1983 attended the IEC Quality Certification System for Electronic Components (IECQ System) and became a full member state of this system in 1986. In this system, CEPREI Lab undertook the duty as the supervision and inspection organization and in 1999, undertook the duty as China national representative office. At present, the international certifications (domestically not included) to be conducted mainly include the ISO9000, QS-9000, ISO/TS16949, TL9000, ISO14000, OHSAS18000, ISO/IEC17799, IECQ and IECQ-HSPM.

In 1988, CEPREI Lab established its electronic product safety certification lab with the engagement in certification of the electronic products, and in 1990 passed the audit by the IECEE and became a CB lab; in 1994, the Lab began to offer the ISO9000 certification with the acquisition of the authorization and approval from the China National Accreditation Committee for Registrars and the China National Accreditation Board for Certifiers of Import-Export Enterprises.

In 1980, CEPERI Lab established the Electronic Product Reliability Data Exchange Network. From 1983 to 1986, it has launched the reliability prediction study on electronic equipment and released the standard of "Reliability Prediction Handbook for Electronic Equipment", and then from that time, the quantitative prediction of the reliability index for electronic equipment has thus had the unified standards.

Besides, CEPERI Lab has also established the first failure analysis (FA) center in China which can perform the components/assemblies detection and failure analysis, DPA for components, test and evaluation of integrated circuits, electronic fittings detection analysis, PCB detection and analysis and the hazard component analysis, having provided thousands of times of components/parts quality analysis, failure analysis and DPA analysis for many enterprises in line of communication, aviation, space, electronics and electrical appliances. In addition, it has also expanded the scope of lead-free soldering and PCBs detection, established a set of procedures and methods of controlling techniques of electronic components and improving the reliability, which significantly improves the quality of the components.

CEPERI Lab, the first lab in China with engagement in the environmental testing, initially focused on the exposure test and has now established a kind of technology platform which can realize the manual simulation of the environmental testing, and has the ability to perform 13 environmental testings, whose items remain the most complete ones in China at present.

CEPERI Lab has several professional departments engaged in the reliability theory and engineering study as well as the testing evaluation and is

equipped with large, medium-sized and small integral environmental stress testing equipment and well-supported testing and analysis instruments and facilities. Therefore, it can provide evaluation and testing services such as reliability determination, evaluation and acceptance for all kinds of products in accordance with the international and domestic standards and can also assist the user to carry out the engineering testing operation such as the reliability environmental stress screening test and reliability growth for all kinds of products.

5. Concern of Chinese companies about the reliability

5.1 Complete import of reliability engineering

Due to the fact that China is now gearing itself to the international market, it requires that products of Chinese enterprises shall stand at the same jumping-off place with the overseas products in terms of the performance, quality and reliability, which makes the requirement for reliability by Chinese companies be expanded, in particular, the requirement for complete import of the reliability engineering. Lots of enterprises wish that they could improve the internal reliability management structure and the reliability level of their products with the aid of the complete reliability import.

5.2 Attention to the reliability testing

Due to the quantitative requirement for the reliability by customers, reliability determination test and certification test, accelerated life test are now drawing the attention, including the testing methods, technology and equipment. In order to promote the product reliability, the reliability testing at the product design and production stage is paid with the attention, such as the environmental testing (a must), reliability enhancement testing, highly accelerated life testing (HALT), environmental stress screening and single environmental stress screening test.

5.3 Attention to the software reliability

With the informatization in society, the function of system/device software will take more and more percentage in the system as compared with that of the

hardware. But up to now, the technology relevant with the software reliability engineering has still not been mature and there still have a great deal of problems to be studied.

If the software engineering is employed to develop the software, then an engineering management system shall be established and specific requirements for the demand management, file preparation, software configuration management, software audit and testing shall be set out before the third party testing work for the software is performed. Typical testing methods include static testing, dynamic testing, white-box testing, black-box testing, basic performance testing, compatibility and limit testing.

5.4 Issue on reliability of lead-free soldering

In order to control the pollution of the electric and electrical products to the environment and ensure the sustainable development of the European Union, the EU has promulgated two directives, WEEE and RoHS, on February 13, 2003. These two directives have a wide application, covering ten categories of electronic and electrical products including the electrical household appliances and communication articles, obligating the manufactures to import the lead-free soldering technique. At the time of importing the lead-free soldering technique, conditions for such techniques have completely changed and the components must conform to the requirement for the lead-free leading technique.

6. Demonstration of reliability cases

6.1 Reliability prediction and improvement of metro power supply system

Working principle diagram of the AC/DC power device of the metro power module, see Figure 1.

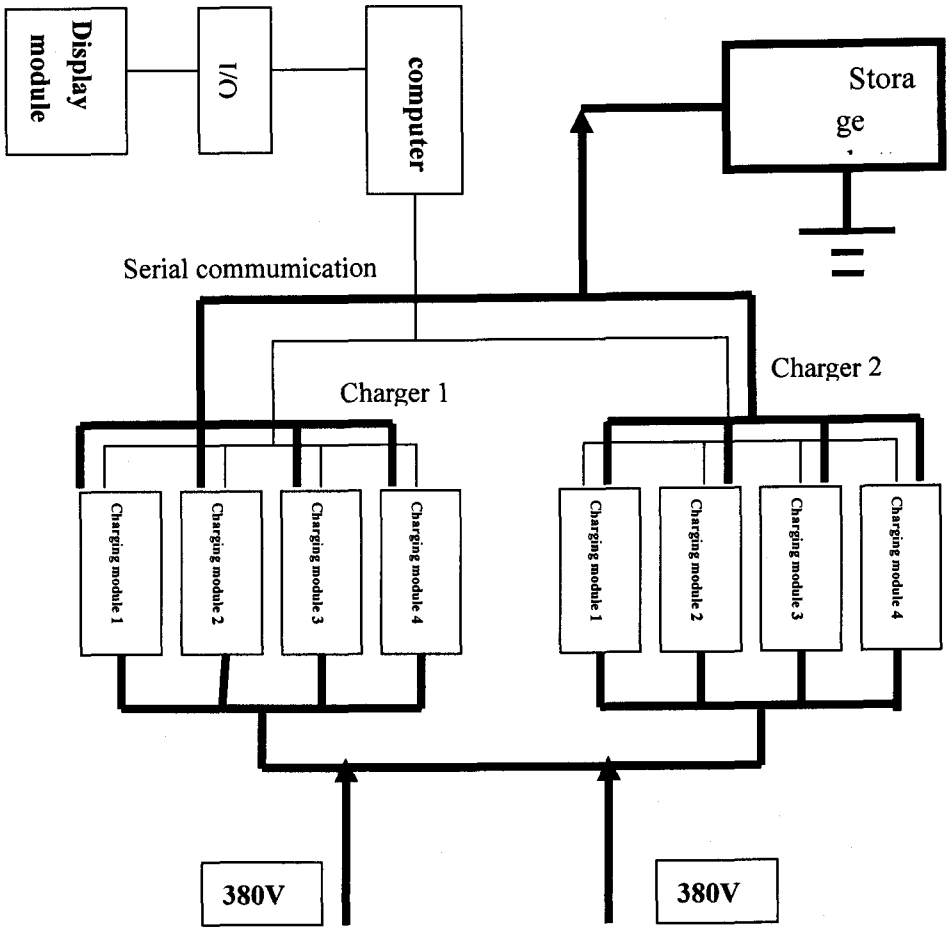

Figure 1 AC/DC power supply diagram of the metro power module

Since the charger has the biggest influence over the safety of the power system, in order to promote the reliability of the AC/DC power supply device, the redundancy method is used, which firstly connect the power supply module in parallel to form the charger and then connect the charging poles in series; by doing so, it can decrease the failure rate by several orders of magnitudes. Please see the redundancy methods in Figure 2.

In the figure 2, the charging module 1, 2, 3 and 4 constitute the parallel-connection model and two chargers constitute the parallel-connection model. As is learned from the reliability prediction that the failure rate of each module is 27.3×10^{-7}/h; as required by the customer that at any time these two modules must work normally, therefore, when taking two of four modules for the calculation, the MTBF of one charger is 396,680 hours, and when these

two chargers are connected in parallel, such MTBF is 595,020 hours, approximately 68 years.

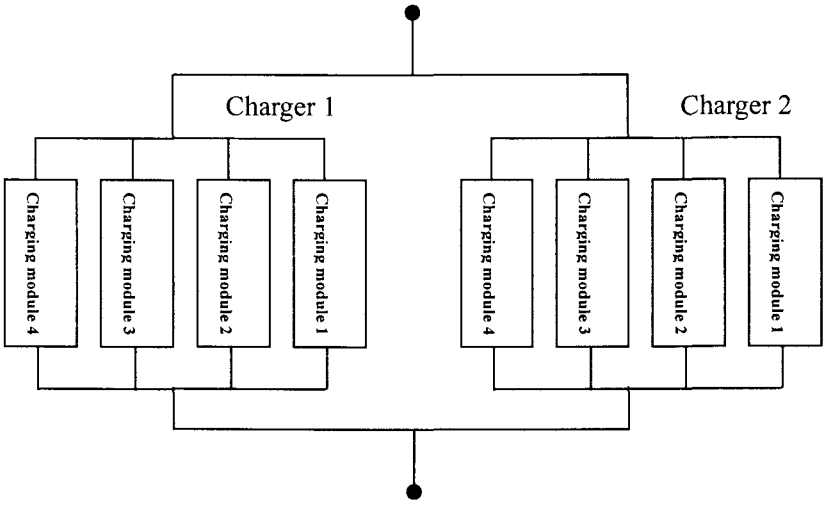

Figure 2. Reliability block diagram of metro AC/DC power supply

However, this kind of connection does not make full use of the reliability of the modules, it is changed to the following connection; see Figure 3.

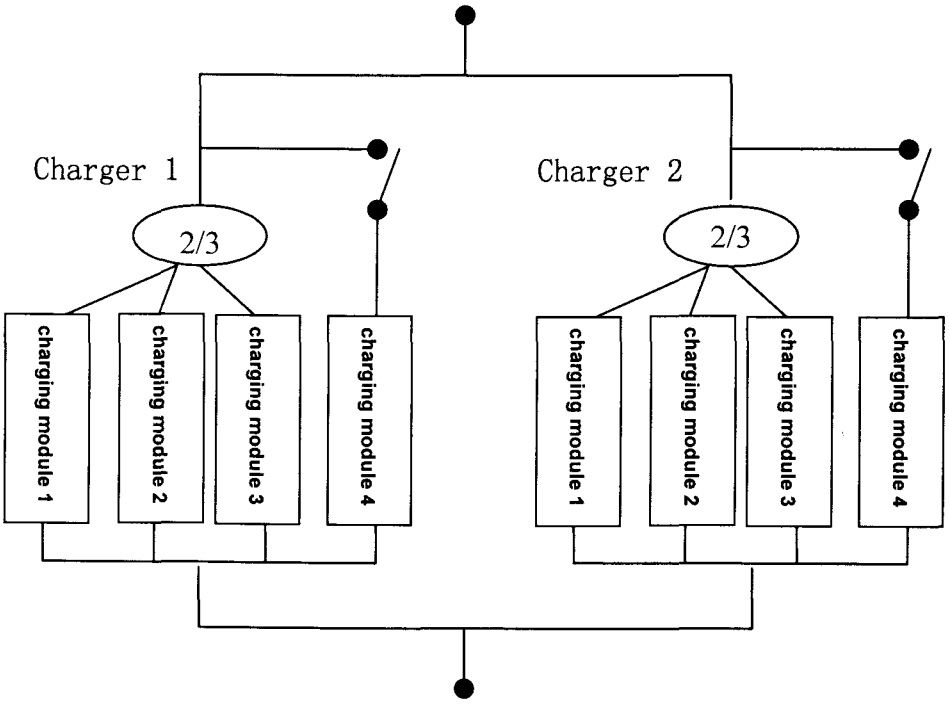

Figure 3. Reliability block diagram of the improved metro AC/DC power supply

In this redundancy method shown in the figure above, the charging module 1,2 and 3 in the charger, after being formed the two-of-three-modules mode (vote system), constitute the cold reserve system with the module 4, then two chargers units constitute the parallel-connection mode.

As is learned from the reliability prediction that the failure rate of each module is 27.3×10^{-7}/h; Based on the reliability calculation model of the two-of-three-modules mode and the cold reserve mode, the MTBF of one charger is 671,304 hours, and when these two chargers are connected in parallel, such MTBF is 1,006,957 hours, approximately 115 years.

Then we can see that with the redundancy method, the reliability of the charging system increases by approximately 2 times, not only the reliability index but also the performance index is ensured.

6.2 Case of the doorbell reliability design

Figure 4 is the schematic diagram of the burglarproof door of one civilian residence, the white button shown in the diagram is used to open the door, actually to open the electromagnetic lock of the door; if you are required to design a circuit to open this electromagnetic lock (the communication parts will be designed separately) , then how could you deal with it?

The first design coming to our head might be: connect the power supply via the button switch to the electromagnetic lock (see Figure 5), and this door will be opened if the user presses this button.

But, is this kind of design reliable?

Of course, generally speaking, the design is good, for its function has been fulfilled (open the door); in effect, this circuit is unreliable.

When pressing the button switch for a long time with this design, the use life could be definitely shortened due to the frequent burning-away of the burglarproof door's power system or the heating of the winding, resulting in the serious loss to the user and enterprise.

Then how to make the improvement; let's think about it for a while.

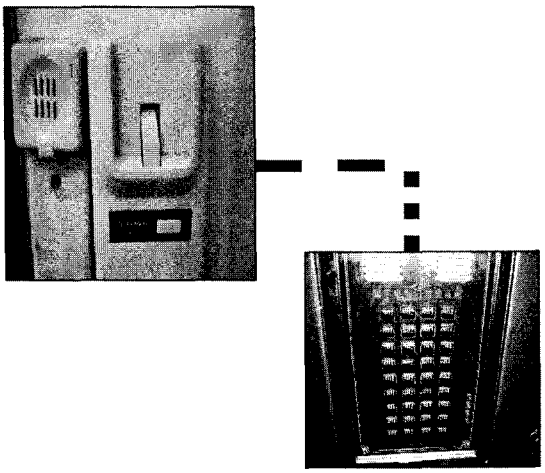

Figure 4 Connection diagram of the burglarproof door

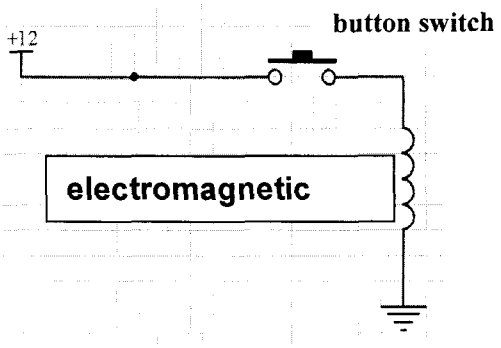

Figure 5 Circuit principle diagram of opening the burglarproof door

6.3 Failure case by sneak circuit

Sometimes, the system failure is not caused due to the damaged components, drift or deviation from the accuracy of the parameters, but the "sneak circuit" in the system.

The so-called sneak circuit refers the signal circuit which has some kind of redundant function or obstructs some kind of normal function. When the designer lacks a general concept for the system, then he/she may not realize the existence of this sneak circuit during the design.

In addition, most of sneak circuits may not function at each operation and could only function when the condition for such malfunction is ready. Therefore, in most cases, it is hard to find this kind of sneak circuit through the test.

Technology of the sneak circuit can be traced back to the launch failure of the Redstone rocket designed by the American Redstone Arsenal.

Figure 6 shows the electric circuit of a car with the sneak circuit, this type here is called as the sneak circuit. Sneak circuit is the circuit in which the current or energy flows along with a irregular path or in a incorrect direction; Figure 6 shows that when the ignition switch is disconnected while the warning switch and braking switch are closed, not only the rear light flashes normally, but also could the radio produce the flashing sound which should not exist.

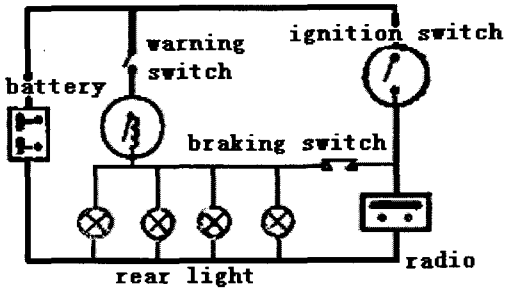

Figure 6 Principle diagram of the sneak circuit in the car

Figure 7 is the principle diagram of one motor's control circuit and also has the sneak circuit; this type here is called as the sneak indication. Sneak indication means the indication causing the confusion or the incorrect indication. Figure 7 shows the circuit of one indicator in the motor's power supply system, but it does not reflect the actual working conditions of this motor.

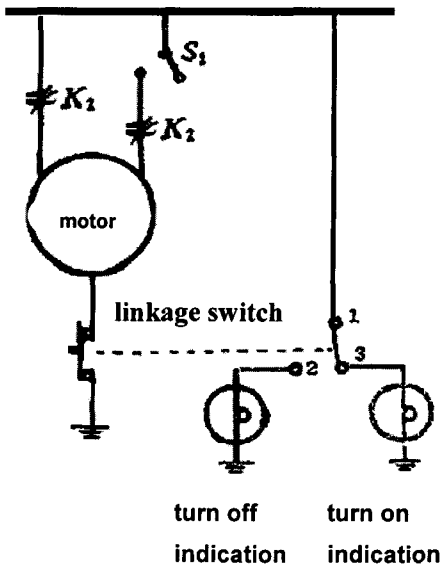

Figure 7 The principle diagram of one indicator in the motor's power supply system

7. Ending

The history of the reliability is a history we should learn a lesson from. We should say that the reliability problems are mostly the low-level problems. Hence, the work for successful reliability must be steadfastly and carefully done, not neglecting the minors and we shall be diligent in making the certification; it is unpractical to improve the reliability in an all-round way by importing several tests and formulas.

The reliability is the time index of the product quality and is the key element to decide whether the product performance/function can be brought into full play in its practical applications. The product reliability is designed into and produced with the product. Therefore, at the beginning of the product design, the reliability analysis shall then be introduced, and perform the reliability testing before the delivery of products and collect the information for reliability growth after the products delivered, and only by doing this, could the product quality be continually improved so as to meet the requirement of the customers.