



Film Capacitors

Quality

Date: May 2009

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1 EPCOS quality system

Basic corporate goals and commitment to total quality are set down in our quality policy.

1.1 Extract from the EPCOS quality policy

The quality of our products and services is an essential part of our corporate strategy, whose paramount aim is total customer satisfaction. Consistent application of a quality management system results in flawless products and a high level of user benefit from our components. Our quality management system always reflects the most stringent international standards.

1.2 Quality management system

The quality management system to ISO/TS 16949:2002 is applied throughout the company and is used to implement the EPCOS quality policy. The implications include:

- As a rule, product and process developments follow the rules of APQP¹⁾,
- Quality tools such as FMEA²⁾, DoE³⁾ and SPC⁴⁾ minimize risks and ensure continuous improvements in conjunction with regular internal audits and QM reviews.

1.3 Certification

The EPCOS quality management system forms the basis for the company certification to ISO 9001:2000 and ISO/TS 16949:2002 that comprises the EPCOS plants and sales organizations. The company certificates are posted on the EPCOS Internet (www.epcos.com/quality).

1.4 Quality programs

Project-oriented improvement programs pursuing the strategic objective of zero defects are set up and conducted by specialist teams.

1.5 Delivery quality

“Delivery quality” means compliance with the agreed data at the time of delivery.

1.6 Failure criteria

A component is defective if one of its features does not correspond to the specification of the data sheet or an agreed delivery specification.

1.7 Traceability

At all stages of production, components are identified by papers accompanying each batch. The completion of manufacturing and testing steps are confirmed and documented in SAP R/3. This ensures the traceability of a batch.

1) APQP= Advanced Product Quality Planning

2) FMEA= Failure Modes and Effects Analysis

3) DoE= Design of Experiments

4) SPC= Statistical Process Control

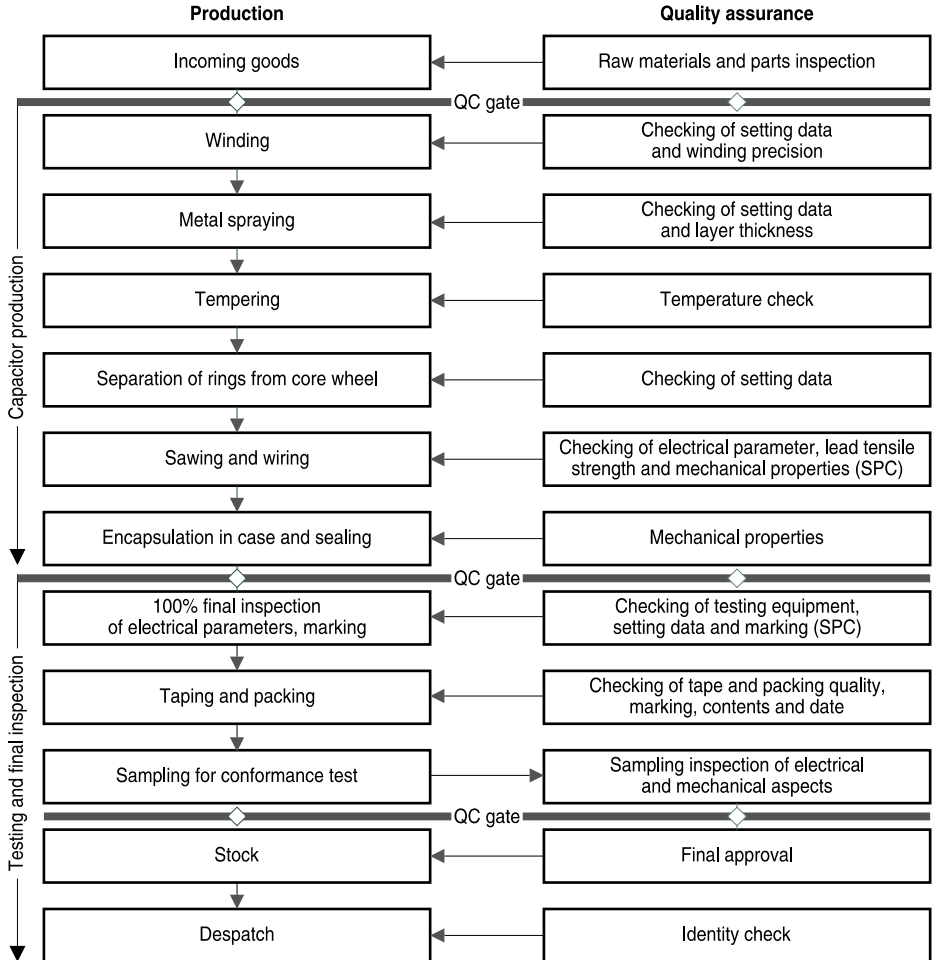
1.8 Final inspection/approval for shipment

Final inspection verifies the major properties of the end products batch by batch, usually by means of fully automated selection tests. Approval for shipment helps certify that products shipped comply with specifications. It includes:

- Testing of principal parameters
- Identification check and visual assessment
- Examination of papers accompanying the batch.

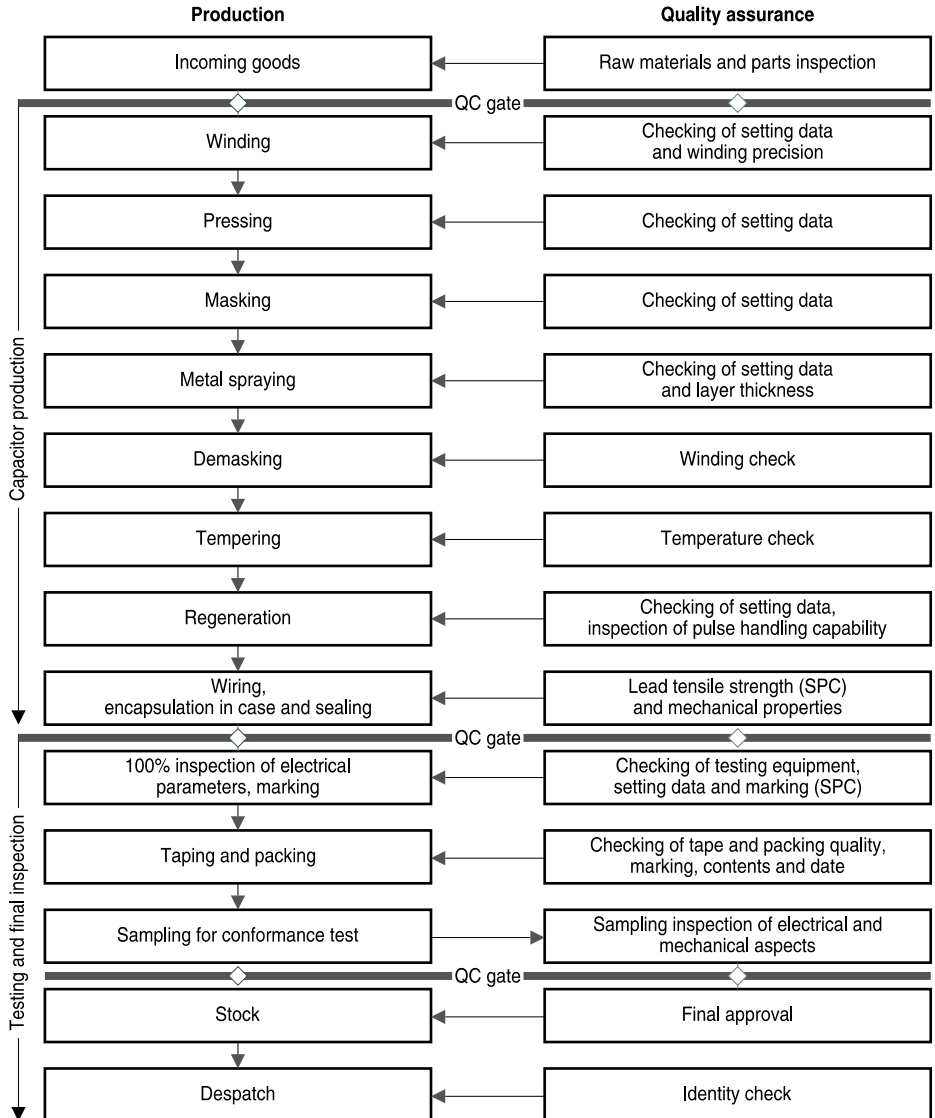
1.9 Manufacturing and quality assurance procedures flow chart

Example: Stacked-film capacitors



KMK1046-L

Example: Wound capacitors



KMK1047-U

1.10 Outgoing quality

The EPCOS quality system aims at continuous improvement and zero defect. The achieved AOQ is specific to the particular product; the current values can be made available on request.

Quality data quoted by EPCOS is always statistical in nature, based on a large number of components, and does not guarantee properties or performance in the legal sense. Customers may demand replacement of any defective components supplied. However, EPCOS' liability does not extend beyond replacement of defective components. This applies in particular to consequential damage caused by component failure.

2 Reliability

The European Power Supply Manufacturers association defines reliability in their "Guide to Understanding Reliability Prediction" as the probability that a piece of equipment operating under specified conditions shall perform satisfactorily for a given period of time. In this Data-Book, two significant parameters are given concerning the reliability of our different products: **Failure rate and service life**. Both figures are always given referred to certain environmental and electrical conditions. While the failure rate is usually given in the conditions indicated in the standard IEC 1709, more realistic conditions are often used for the service life. In any case, in the following sections it will be shown how to estimate the failure rate and service life of our products for operating conditions different to the standard reference temperature and voltages.

2.1 Failure rate (long-term intrinsic failure rate)

The failure rate or **intrinsic failure rate** (λ) of any product is the **statistical number of units** failing per unit of time in the **intrinsic failure period** (see figure 1). The failure rate changes throughout the life of the product. In the meaningful period, however, empirical evidence has shown that the failure rate can be assumed constant in time (λ).

The failure rate is expressed in units of fit (fit = failure in time), where 1 fit = $1 \cdot 10^{-9}/h$ (1 failure per 10^9 component hours)

2.2 The Bathtub curve

The evolution of the failure rate in time during the lifetime of our products follows the typical *bathtub* curve. Figure 1 shows the characteristic shape of this curve, highlighting the three main regions that can be distinguished in a typical lifetime of any product. The first region, starting when customer use commences, is characterized by a relatively high but rapidly decreasing failure rate. This is related to what is called **infant mortality**. The time scale here ranges from hours to weeks. After this transient, the failure rate levels off, remaining roughly constant for the majority of the useful life of the product. This long period is usually called **Intrinsic Failure Period**, and the failure rate is then called **Intrinsic Failure Rate**. Finally, if units from the population remain in use long enough, failure rate begins to increase significantly again as materials wear out and degradation failures occur. This is the **wear out failure period**.

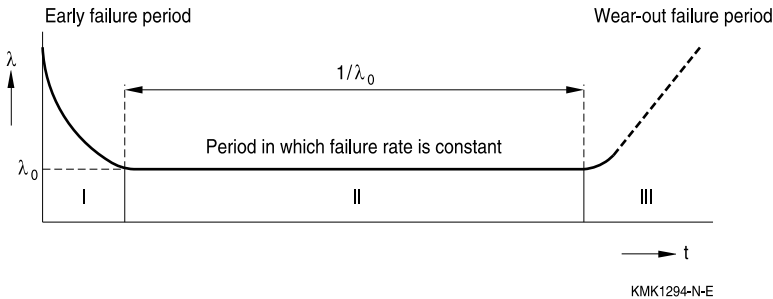


Figure 1
Typical failure rate curve of a product

It is important to remark that time scales in this figure are arbitrary. In particular, the wear out (III) and early failure period (I) have been represented as much longer than they are in reality, when compared with the intrinsic failure period (II). In a real case, this latter period covers several decades, and therefore it is clearly much longer than the infant mortality period (which, as it was mentioned, can last a couple of months at maximum). Additionally, EPCOS capacitors are specially treated during production in order to eliminate early failures, and the early failure period is further reduced. The wear out failure period, however, is not as relevant as the other two, for at the end of the intrinsic failure period, most of the samples will have failed. Due to these two considerations, it can be understood why the intrinsic failure period can be interpreted for our products as **the service life of the product**:

$$\text{Service Life} \equiv t_{\text{SL}} \approx \text{Intrinsic Failure Period}$$

Failure rates stated in this data book refer to this constant failure rate phase (service period), and, as will be discussed next, they apply to the reference load and reference conditions. The failure rate for each component type is stated in the respective data sheet together with the corresponding reference load and failure criteria. Normally, no failure rate is stated for EMI suppression capacitors because of their direct connection to the mains, where electrical conditions are not stable, and there is a potential for overvoltage to occur.

2.3 Failure rate and mean operating time to failure (MTTF)

Several conclusions can be extracted from the assumption that during the service period, the failure rate, $\lambda(t)$, is actually constant:

$$\lambda(t) \approx \lambda_0 = \text{const.}$$

In particular, it can be demonstrated that the distribution of failures is exactly exponential in this approximation, being the cumulative distribution function:

$$F(t) = 1 - e^{-\lambda_0 t}$$

This function gives the probability that a product fails by a specified time t . It is often interpreted as the population fraction failing by time t .

The *reliability function*, $R(t)$, also called the survival function, is often interpreted as the population fraction surviving time t . $R(t)$, being the probability of success, is therefore the complement of $F(t)$:

$$R(t) = 1 - F(t)$$

Finally, another extremely significant definition is the mean time to failure (MTTF), which in general is the expected life of a non-repairable product. It can be defined in terms of the reliability function:

$$MTTF = \int_0^{\infty} R(t) dt = \int_0^{\infty} e^{-\lambda_0 t} dt = \frac{1}{\lambda_0}$$

In any case, the MTTF is a measure of the centre of a life distribution. In the exponential approximation, the MTTF is the same as the median of the distribution (most probable case).

At this point, it is essential to understand any figure of MTTF or λ (and any other magnitude derived from them) as statistical averages. A **constant failure rate** actually means that failure occurs **randomly** with a mean frequency given by the inverse of λ . It is also very common (but completely erroneous) to assume that the MTTF indicates a minimum time between failures, which is absolutely not the case. On the contrary, failures will occur randomly, the distribution being:

$$F(t) = 1 - e^{-\lambda_0 t} = 1 - e^{-\frac{t}{MTTF}}$$

It is however true that, for a given period of time $[0, t]$ the bigger the MTTF, the smaller the probability of finding a failure. Suppose we are testing, in the proper climatic and electrical conditions (given by IEC 1709), a high enough number of units of our product (whose $\lambda_0 = 2$ FIT, i.e. $MTTF = 5 \cdot 10^8$ hours). The previous equation is then telling us that after $5 \cdot 10^8$ hours, 63% ($\sim 1 - 1/e$) of the pieces will have failed. Please observe that even in the ideal case (a very big sample) some of the pieces will have failed before this time ($5 \cdot 10^8$ hours). Attending to the exponential distribution, for example, 1% of the pieces will have failed after $\sim 5 \cdot 10^6$ hours, i.e. 100 times earlier than the MTTF. We stress, once again, that this is a statistical value that may present some deviations in different realizations.

2.4 Reference conditions and failure rate calculation

As already said, standard failure rate figures are always calculated referred to certain climatic, mechanical and electrical reference conditions. The exact conditions are indicated in the IEC 1709 norm for the different passive components. In case of film capacitors:

- Among others, the relevant **climatic conditions** (as per IEC 721-3-3, class 3k3), read:

Temperature limits	Rate of change of temperature	Condensation
+5 to +40 °C	0.5 °C/min	No

Attention is drawn in the mentioned standard to the fact **that combinations of the environmental parameters given may increase the effect on a particular component**. As we will be discussing later on this document, this especially applies to the presence of high relative humidity in addition to biological conditions or to conditions of chemically active substances.

- The **electrical stress** should be 50% of the rated voltage at 40 °C ($V/V_R = 0.5$).
- The **mechanical stress** is also specified in IEC 721-3-3 with class 3M3.

For a correct understanding of failure rate figures, it is essential to take into account that any failure rate estimation is related to these general conditions and applies to the constant failure rate period (as explicitly mentioned in the IEC 1709 standard). Components may however not always operate under these standard conditions. In which case, failure rates different to those given for the reference will be expected.

In the case of film capacitors, the two most relevant parameters affecting the failure rate are temperature and voltage. In the IEC 1709 standard, models for stress factors are consequently applied in order to convert the failure rates under reference conditions to values applying for operating conditions. The conversion should be carried out according to:

$$\lambda = \lambda_{ref} \cdot \pi_V \cdot \pi_T$$

where the correction factors are those indicated in following tables:

T (°C)	π_T	V/V_R	π_V
≤40	1.0	10%	0.26
50	1.8	25%	0.42
55	2.3	50%	1.00
60	3.1	60%	1.42
70	5.2	70%	2.04
80	9.0	80%	2.93
85	12	90%	4.22
90	16	100%	6.09
100	33	110%	9.00
105	50	120%	13.00
110	77		
120	206		
125	346		

2.5 Service life t_{SL}

In the context of the exponential approximation and, following our earlier reasoning, the service life of our product is directly related to the duration of the intrinsic failure period (II, of the bathtub curve), which is also proportional to the inverse of the constant failure rate λ_0 . Given the statistical nature of this figure, any estimation for a certain product will be inherently linked to a certain confidence level. We therefore calculate the service life after:

$$t_{SL} = \frac{p}{\lambda_0}$$

where p is a factor related to the confidence level of the estimation:

confidence level (%)	p
37	0.716
63	0.333
75	0.207
90	0.076
95	0.037
98	0.015

It is important to remark that using the proposed formula, the environmental and operating conditions for which t_{SL} applies are exactly those of λ_0 . For a detailed example of good use of the formula and the correction factors, see next section.

2.6 Practical example

Suppose we have a product that will be used at the rated voltage and a stable temperature of 85 °C. For estimating the failure rate of this product, an accelerated endurance test has been performed at the reference conditions (40 °C & V = 0.5 V_R). Further details of the test are:

- Number of components tested (N): 20000
- Duration of the test (T): 50000 hours
- Number of failures at the end of the test (n): 1

A good estimator for the failure rate can then be calculated in terms of the total testing time, which results of multiplying the duration of the test by the number of samples tested (TTT = N · T),

$$\hat{\lambda}_{ref} = \frac{n}{TTT} = \frac{n}{N \cdot T} = \frac{1}{20000 \cdot 50000 \text{ h}} = 1 \cdot 10^{-9} \text{ h}^{-1}$$

Accordingly, we conclude that the failure rate of this product operating at reference conditions is $\lambda_0 = 1$ fit:

$$\lambda_{ref} = 1 \cdot 10^{-9} \text{ h}^{-1}, \text{ at } (40^\circ\text{C} \ \& \ V = 0.5 \text{ V}_R)$$

The standard factors shown in previous section can be used for calculating the failure rate at the operating conditions:

$$\lambda_0^{op} = \lambda_{ref} \cdot \pi_T^{85^\circ\text{C}} \cdot \pi_V^{V_R} = 1 \cdot 10^{-9} \cdot 12 \cdot 6.09 \text{ h}^{-1} = 73.10 \cdot 10^{-9} \text{ h}^{-1} \approx 73 \text{ fit}$$

And the corresponding service life under the same operating conditions can be then calculated with a *98% confidence level* after:

$$t_{SL,98\%}^{op} = \frac{p^{98\%}}{\lambda_0^{op}} = \frac{0.015}{73.1 \cdot 10^{-9}} h \approx 200000$$

Now, note that if we wanted to restrict our estimation to a lower confidence level, i.e. 90%, the result would then have been:

$$t_{SL,90\%}^{op} = \frac{p^{90\%}}{\lambda_0^{op}} = \frac{0.076}{73.1 \cdot 10^{-9}} h \approx 1000000$$

Both figures are compatible, and should be interpreted as follows. For a big enough sample of products that are being tested under the given operating conditions, 98% of the pieces will be fully operative after 200000 working hours, but after 1000000 working hours, only 90% of them will remain.

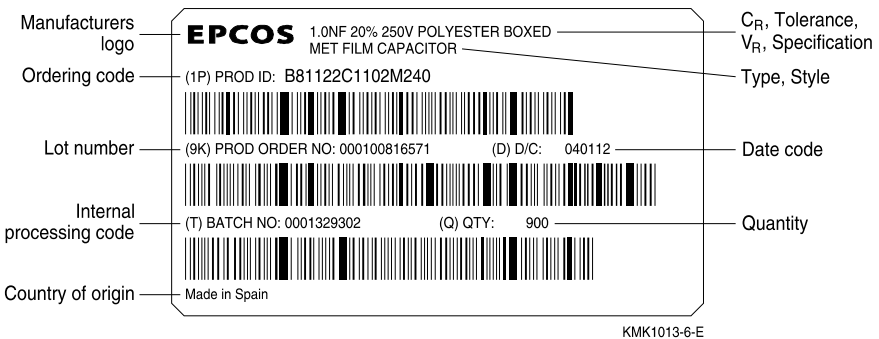
3 Identification and traceability

At all stages of production, components are identified by papers accompanying each batch and documenting completion of manufacturing and testing steps. This ensures the traceability of a batch.

After shipment, traceability is ensured by a code on the component and/or its packing.

3.1 Bar code label

The packing of all EPCOS components bears a bar code label stating the type, ordering code, quantity, date of manufacture and batch number. This enables a component to be traced back through the production process, together with its batch and test report.



5) RMA = Return of Material Authorization

3.2 Customer complaints

If a fault occurs in a product despite careful manufacture and testing, please contact your local sales organization. They will register your complaint as an RMA⁵⁾ process and forward it to the relevant technical departments for rapid handling.

EPCOS treats technical complaints according to the 8D⁶⁾ methodology; i.e. with the use of interdisciplinary teams who aim to implement rapid countermeasures and sustained corrections and answer all complaints with an 8D report.

In order to be able to deal quickly and smoothly with complaints, the following data are helpful:

- Number of components subject to complaint or returned
- Fault description
- How and when was the fault detected?
- Logistics data (date code, delivery note no.)
- Operating conditions
- Operating duration up to occurrence of the fault
- Measurement parameters in the case of divergent technical data

In the event of transport damage, we would ask you to describe this in more detail and if required to mark it so that it can be distinguished from any further damage sustained during the return shipment. The original package should also be checked and any damage to be described. In order to avoid further damage, the original packaging should also be used for the return shipment.

In case of receiving a damaged delivery, please document this damage with a signature of the forwarding company on the delivery papers.

To help to improve the service, please report the failure at the acceptance of the goods in case of transportation failure.

3.3 Conditions of use

EPCOS products may only be used in line with the technical specifications and installation instructions and must comply with the state of the art. Non-observance of limits, operating conditions or handling guidelines can lead to disturbances in the circuit and other undesirable consequences such as a higher failure rate.

In this connection, please note the “Important notes” on page 2.

Should you have any application-referred questions, please contact our experts, who will be pleased to advise you.

5) RMA = Return of Material Authorization

6) 8D = 8 disciplines