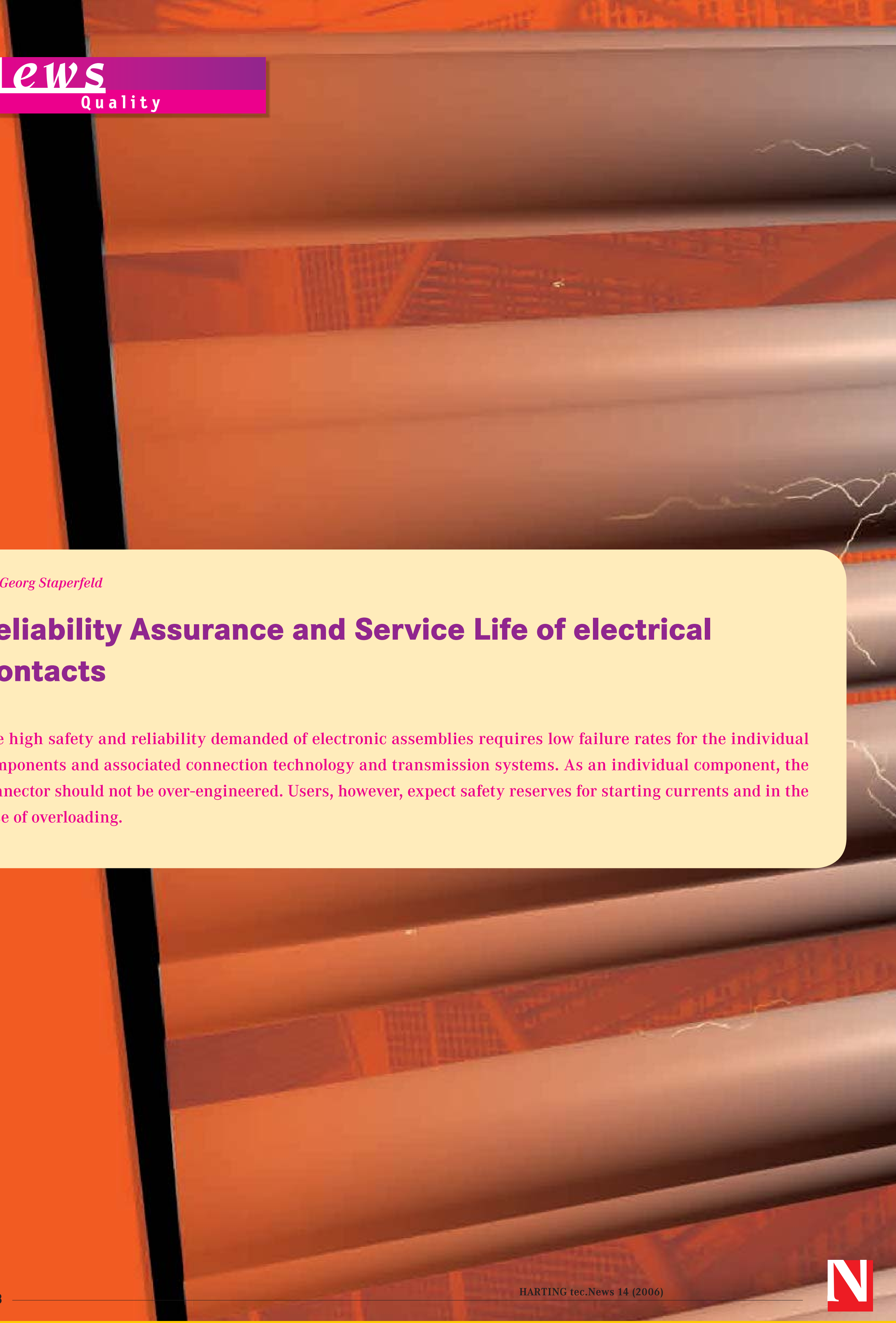
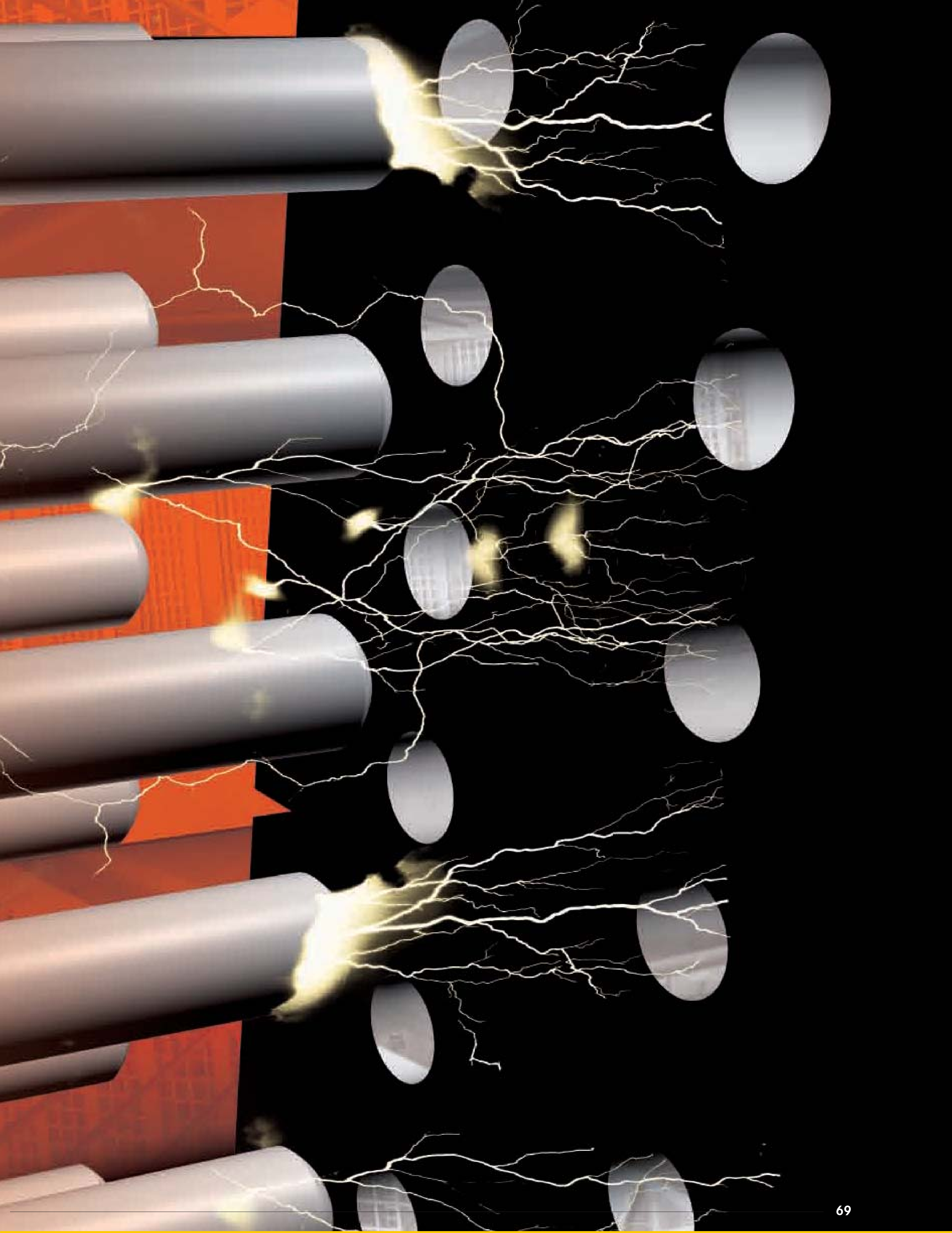


Dr. Georg Staperfeld

Reliability Assurance and Service Life of electrical Contacts

The high safety and reliability demanded of electronic assemblies requires low failure rates for the individual components and associated connection technology and transmission systems. As an individual component, the connector should not be over-engineered. Users, however, expect safety reserves for starting currents and in the case of overloading.



MTBF (mean time between failure), MTTF (mean time to failure), FIT (failure in time) failure rates and service life are reliability parameters that are also being increasingly demanded for connectors.

In the past, manufacturers of connectors found it difficult to make confident statements about the reliability of new developments since, on the one hand, there is a lack of experience in the field with innovative product ideas and, on the other hand, there is great deal of diversity in terms of possible uses and applications and the service life of the products in general.

In response to this problem, HARTING has developed a method to determine the failure-free time due to design and construction, namely the time that separates the normal service life and usage duration of a connector contact from the wear-out failure period. This makes use of the fact that the service life follows an Arrhenius Law and is based on the extrapolation of laboratory measurement values. This statement on the reliability of a design supplements the empirical, calculated MTTF value.

In a second step, a method to determine the average service life (MTTF) of connectors is introduced on the basis of physical failure mechanisms.

INFLUENCE OF QUALITY AND DEVELOPMENT ON RELIABILITY

With regard to material fatigue and the failure of electronic components, the Weibull distribution (named after the Swedish engineer and mathematician, Waloddi Weibull) identifies the categories of failure: I early life, II normal life and III wear-out. A high degree of early-life failures always indicates a difficult or immature manufacturing process. With the exception of design defects, the failure rate $\lambda = \frac{1}{MTTF}$ during the service life is largely determined by the quality and capability of the manufacturing process. In the case of current, highly-automated manufacturing processes, the failure rate $h(t) = \lambda$ with process capabilities for 6σ and products without serious design weaknesses tends towards zero $h(t) = \lambda \rightarrow 0$.

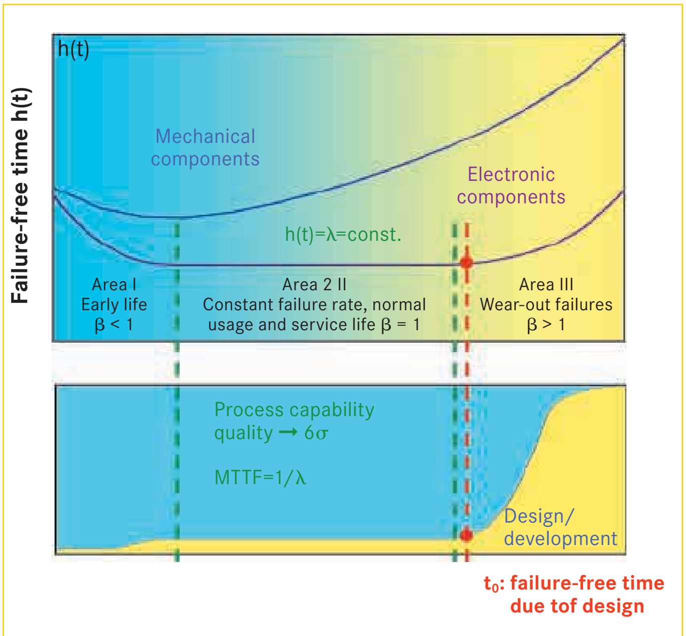


Fig. 1: The end of the normal life or usage period is determined in product development and design.
"Bathtub curve" source of failure rates: Taschenbuch der Zuverlässigkeit und Sicherheitstechnik, Hanser Verlag

Wear-out failures bring an end to the normal service life. The start of this period is determined in development and during product design.

RELAXATION OF CONTACT PRESSURE AS PHYSICAL LIMITING VALUE

Safe contact closure of a connector contact is guaranteed if the pressure $\sigma = \frac{F_N}{A}$ in the contact point does not fall below the minimum design value so that foreign layers are safely penetrated under dry-friction conditions. The precious metal coating and geometry of the contact system are taken as fixed variables in a first approximation, so that the time-dependent variable on the contact pressure represents the normal force. Reliability is thus determined from the relaxation of the spring contact as a function of time.

USING THE ARRHENIUS DIAGRAM TO DETERMINE SERVICE LIFE

It is necessary to determine for how long and at which contact temperature the normal force of the spring contact remains above the minimum value.

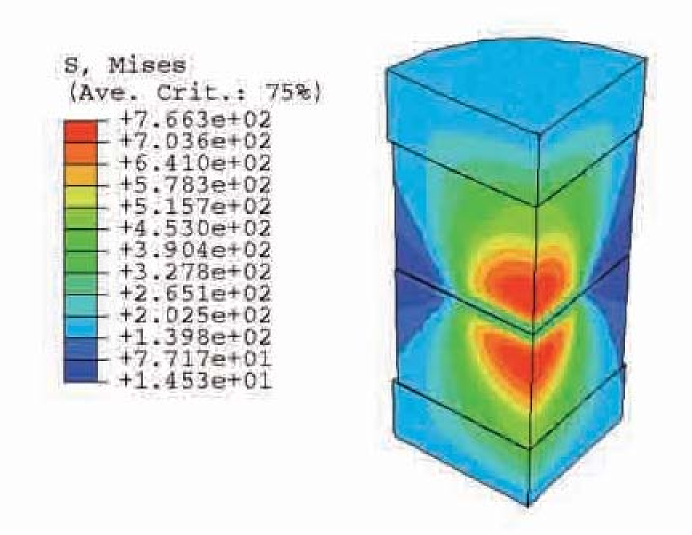


Fig. 2: Simulation to calculate the minimum contact pressure in the development phase

In general, the mechanical stress is given by the expression, $\sigma_S \approx \ln(t)$, so that the logarithmic representation of the spring forces measured results in a linear variation. From the point of intersection of the extrapolated straight lines with the minimal normal force, it is possible to interpolate the time period during which the contact functions reliably.

The function named after the Swedish scientist and Nobel prizewinner, Svante Arrhenius, describes diffusion characteristics and is thus ideal for application to relaxation processes.

In a laboratory investigation, the test pieces are stored at various temperatures and the normal force of the spring contacts is measured over the duration of the storage period.

The time values obtained for the reliability range are plotted reciprocally against the logarithm of time in the Arrhenius diagram.

From this, we can now derive the reliability of the design in years for the contact temperatures during usage.
For example, with a continuous temperature load in operation at T_K = 110°C , the contact is still operational after t_0 = 100 years (t_0 = *the failure-free time due to design).*

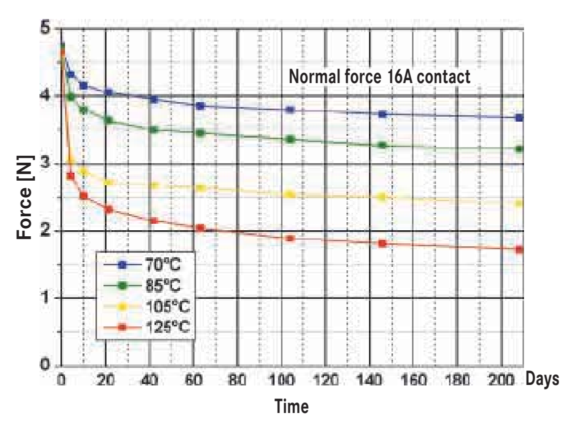


Fig. 3: Normal or spring force as function of time at temperatures T= 70°C, 85°C, 105°C and 125°C

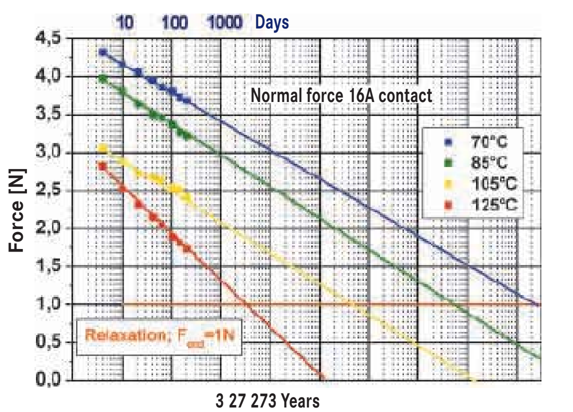


Fig. 4: Extrapolation of the relaxation measurements to determine the reliability range

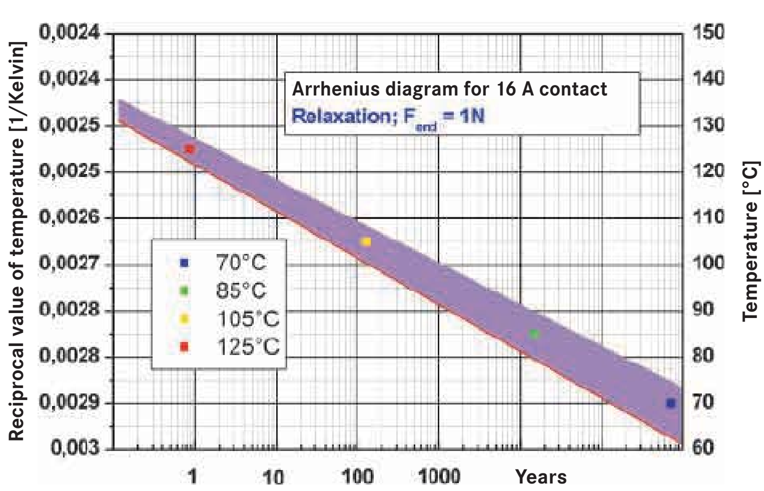


Fig. 5: Arrhenius diagram from the experimentally determined reliability values

The contact temperature T_K is determined from the current load and ambient temperature in the application. Using these parameters, it can be taken from the diagram for the current-carrying capacity.

CONFIRMING THE MODEL AND MINIMUM CONTACT PRESSURE

To confirm the minimum normal force due to design, a second batch of test pieces was subjected to 200 insertion cycles before subjecting to load with dry heat.

After the relaxation test, namely in the pre-aged condition, the test pieces were subjected to a mixed-gas test in accordance with IEC 60068-2-60, vibration load and climatic sequence for 21 days. The test variables were the contact resistance and the current-carrying capacity.

The current-carrying capacity is reduced by 5 % from its initial value before heat storage. This is due to the somewhat higher constriction resistance as a result of relaxation.

The selected stresses and measurements of the test pieces after ageing thus confirm the minimum contact pressure and also our model to determine the service life or failure-free time.

DETERMINATION OF AVERAGE SERVICE LIFE ON THE BASIS OF PHYSICAL FAILURE MECHANISMS

We conducted the following static load tests: dry heat, insertion cycles, mixed flowing gas test, climatic sequence, shock and vibration. The physical failure mechanisms assumed as the basis of the model were: relaxation, abrasion and corrosion.

On this basis, with a sufficiently large sample size and knowing the acceleration factors, it was also possible to determine the MTTF values in the test laboratory. The spot sample has to be sufficiently large (at least 500 contacts) since the load time and upper load limit cannot be extended indefinitely, otherwise the results obtained would refer to the period of wear rather than to the period of usage.

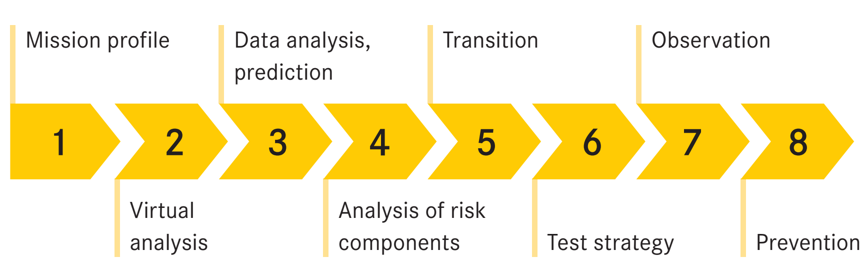
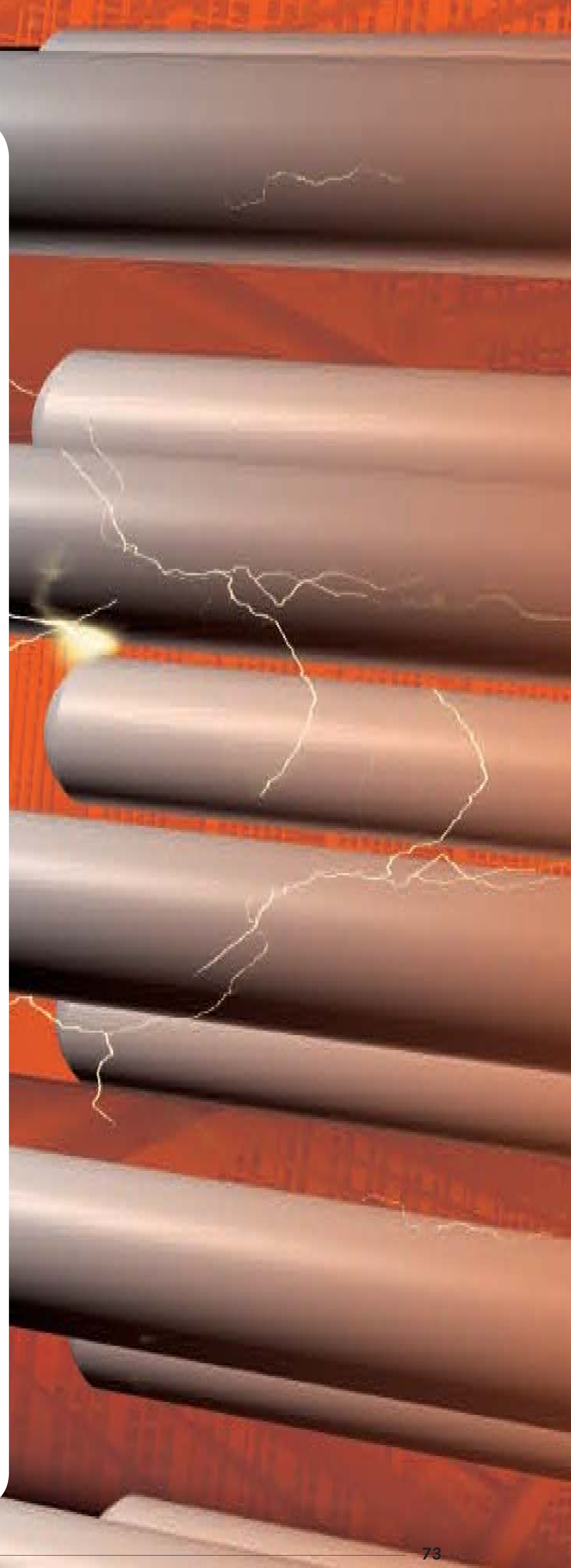


Fig. 6: Procedure for reliability management in accordance with VDI 4003 (draft)



Scientifically confirmed acceleration factors determined in the 1980s by W.H. Abbott at the Battelle Institute and in the 1990s by the Swedish Corrosion Institute are assigned to the corrosivity as a result of mixed flowing gases (MFG).

This research work confirms the acceleration factor to a first approximation, according to which one day under MFG load corresponds to one year's actual application under outdoor conditions.

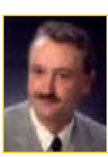
For the other loads, acceleration factors have already been determined in the automotive sector. However, they can also be determined from experimental data using the Arrhenius function.

After inclusion of the acceleration factors, the failure rate for the 16A contact under strict industrial-gas conditions and in the external area of traction engines is determined as $\lambda_{Application}$ = 0.4 FIT and the MTTF value as MTTF = 2375 * 10^6 h for the period of service life and a confidence interval of 90 %. The confidence interval is determined from the application of the χ^2 function.

COMPONENTS IN RELIABILITY MANAGEMENT

HARTING has also developed reliable forecasts for simulation models for characteristics such as contact pressure, current-carrying capacity and relaxation (see tec.News 13). On the basis of the Arrhenius model, it is therefore possible to ensure reliability already during the development stage and consequently design it into the product.

These two important components for assuring reliability during testing and in the simulation phase are closely interlinked and fit seamlessly into reliability management (VDI 4003 – draft).



Dr. Georg Staperfeld
Senior Manager
Corporate Technology Services
HARTING KGaA
georg.staperfeld@HARTING.com