1. Abstract
Quality Management in a testing laboratory aims at improving all aspects of the investigation’s quality, i.e. getting uncertainty low, repeatability high, responsibility clear, informative flow transparent and the client’s wishes fulfilled. In the present case, those aims are combined in the pursuit of the laboratory’s accreditation, i.e. the external approval of the lab’s competence for performing the described investigation.

The present paper describes the installation of the organisational and technical processes as given in DIN EN ISO/IEC 17025 [1]. Eliminating ambiguity and subjectivity from the test description proved to be the most challenging step. Involvement of all employees including the laboratory’s management is a prerequisite for the success of accreditation. An essential element of the quality management system is furthermore the uninterrupted support of all processes to create a situation of stability.

Thus the two key elements of KAIZEN – improvement and continuity – are already realised. This highly successful concept will be further extended by gaining accreditation for all testing laboratories within the department “Verification and Testing, Traction” in the near future.

2. Introduction
Following a recommendation of the German Railway Federal Office (Eisenbahnbundesamt EBA), the testing laboratory “Pantograph-Catenary” at the Research and Technology Center (FTZ) of the Deutsche Bahn AG in Munich started the process of accreditation. As a benefit
of such an action improvements in repeatability, transparency, quality of the tests and client orientation were expected. With the EN/ISO/IEC 17025 serving as a guideline, the establishment of a quality system with an appropriate quality management handbook proved to be one of the major milestones on the way. At the same time, the transfer of the new set of rules to a number of pilot laboratories throughout FTZ proceeded. In order to achieve a swift and competent feedback as well as to avoid regulations that cannot be put into practice, the project team was combined from the laboratories’ Quality Representatives (QB). In the selection of the laboratories, a high degree of diversity was envisaged. Thus, the pilots cover the whole scope of FTZ’s activities with both stationary and mobile laboratories.

The laboratory serving as an example here, is the mobile testing laboratory “Pantograph-Catenary”. One of the main tasks of this laboratory is the performance of online tests of the dynamic contact force between catenary and pantograph. The energy for traction of electric rail vehicles is transmitted from the catenary to the vehicle by means of a pantograph. The contact force between catenary and pantograph has to keep well between an upper and lower boundary. Keeping under the upper force limit guarantees the function and integrity of the catenary. The lower force limit must be surpassed to avoid arching, as arcs lead to brittleness of the contact strips which quickly leads to failure. Low values of the contact force are generally more favourable than high ones in order to keep the abrasive wear of the contact strips and the catenary low. Consequently, for new combinations of railway vehicle and pantograph the contact force between catenary and pantograph must be investigated. The successful performance of test drives is a mandatory prerequisite to gain the EBA’s approval for running the new system on German railway lines.

The investigation comprises a number of test drives with the railway vehicle in question under the type of catenary for which the EBA approval is envisaged. The investigation starts with an aerodynamic optimisation of the pantograph. Following the successful aerodynamic optimisation, test drives are performed for different speeds, directions and railway line parameters. During all test drives, the contact force as well as the uplift of the catenary must remain within the bounds defined in the document “Technischer Netzzugang für Fahrzeuge” [2].
3. Quality Management in Mobile Laboratories

3.1. Process orientation

In order to facilitate the realisation of the DIN EN ISO/IEC 17025 “General requirements for the competence of testing and calibration laboratories”, a Quality Management Handbook (QMH) has been established which is valid throughout the FTZ. In the QMH, the usual activities of a laboratory are split into 12 business processes. Every single process is described as a flow chart wherein for each step the person in charge is noted as well as those who are involved and those who have to be informed.

Figure 1 shows the existing processes in the FTZ as well as their grouping in “management processes”, “business processes” and “supporting processes”.

Using processes as ordering system in a business unit combines the advantage of great flexibility with a minimum but complete set of rules. This ordering system is a robust tool...
even if a new field of business is added to a business unit, or if any restructuring measures are taken.

3.2 Putting the QMH into practice

Putting the regulation of the QMH into practice means checking process by process if all the steps of the process description are being followed. At the beginning of this procedure the following overview might prove helpful for more effective planning:

Step 1: Finding out, what test(s) shall be part of the accreditation and who is in charge of the project.

Step 2: Description of the testing procedure, definition of necessary testing systems and auxiliary systems, if applicable: definition of normative references where the testing procedure is described.

Step 3: Description of the installation for the testing system, the online calibration procedures, creation of a model testing protocol, calculation of overall measuring uncertainty.

Step 4: Completion of all regulations specific for the business unit.

Step 5: Definition, marking and organisation of all testing and auxiliary testing systems

Step 6: Regulations for other processes.

The average time for each of those sections in our experience was approximately 4 to 8 weeks. Special attention has to be paid to the description of the testing procedure and all the activities related to the performance of test drives (step 2 and 3). The documents created in the framework of those steps constitute the centre of the accreditation procedure. If no normative references exist for the description of the testing procedure, this document must give sufficient detail to serve as a “recipe” for measuring. However, this should not unduly limit the applicability for other test drives with the same kind of measuring task. When the test procedure is described, the following questions have to be addressed:

- What is a testing system, what is an auxiliary system?
- When do we stop the test (successfully/not successfully)?
- In which cases don’t we start testing?
- What steps are necessary for the successful performance of the test?
- How can be ensured that two people gain the same result in the evaluation of the measurements?
- What should be put in a report?
- What degree of uncertainty is connected to the measuring result?

The organisation of the testing systems is another key element of accreditation. In cases where only a subset of the laboratory’s tests are in the scope of accreditation, there might arise the question whether or not to mark, calibrate and organise all testing systems within the laboratory. A suitable compromise is to mark all measuring systems of one kind which appear in any accredited test procedure, but not necessarily to calibrate them all. For example, if a digital multimeter is needed in one test which is in the scope of accreditation, all of the business unit’s digital multimeters have to be marked and organised in a suitable list but only those used in the test have to hold a topical calibration tag. For better distinction, the other multimeters can be marked with a sign “testing system -- not calibrated”.

The distinction of testing systems and auxiliary testing systems in practice can be clarified by finding out whether the result of this sort of measuring equipment, especially its numeric value enter into the measuring result. If it furthermore might appear in the testing report, the piece of equipment is a measuring system, otherwise it can be treated as the auxiliary measuring system. As such, it still is subject to maintenance but does not have to be kept in a calibrated state.

4. Examples of Kaizen
Kaizen (which in Japanese means improvement in a gradual and orderly, continuous way) shows in many ways once the accreditation process is started. Some examples illuminate the many ways of Kaizen at the example of a testing laboratory.

- Installation of automatic measuring systems where possible
  Combined with the test drives for measuring contact force between catenary and pantograph, the uplift of the overhead line in question is measured. The measuring equipment for the uplift is set up in a car and driven to a suitable position next to the
overhead line in question. During all test drives, a member of the workgroup remains at the measuring site in order to inform the measuring team in the test vehicle on the topical displacement value, wind speed and to ensure the correctness of the measured data. In the course of the accreditation process it appeared to be more desirable to employ this person for more sophisticated tasks. Consequently, first steps towards fully automated displacement systems have been taken, a prototype with automatic data transfer is working since June 2000 as described by H. Möller et al. in [3].

- **Reduction of person-related tasks**
  A high degree of specialisation in the steps which are part of the measurement reduces flexibility in the workflow. In this respect it is reasonable if more than one person in the measuring team is qualified to prepare the pantograph for measurements, to install or to calibrate the measuring system, to organise and perform test drives. Qualification activities have been intensified to reach double and triple coverage of each task.

- **Reduction of measuring uncertainty**
  The effect of many sources of the overall measuring uncertainty can be reduced if high quality equipment is used, good care taken in the calibration process and constant plausibility checks are performed during the test drives. In agreement with the E DIN EN 50317 [4], a major reduction of the systematic measuring uncertainty is possible by correcting the measured contact force with the inertia forces due to the effect of the mass between the sensors and the contact point of the pantograph. This can be done by measuring the acceleration of these components. Following this rule, acceleration sensors have been added to the measuring system and test drives have been performed. Future steps in this respect aim at higher robustness of the sensors as well as evaluating the exact impact of the acceleration of the contact strips on the overall measuring result.

- **Reduction of diversity of measuring equipment**
  Maintenance is a process which aims at keeping the measuring equipment in good condition for the application in a test drive. If several generations of test equipment are kept simultaneously, two major factors should be considered: compatibility of all components of the measuring system of all generations facilitates the set-up of the measuring equipment prior to a test drive. Furthermore each new generation of measuring system should follow a similar maintenance and handling procedure as the previous
5. Conclusion
While preparing a testing laboratory for accreditation, a number of positive side effects have been identified. These include

- Creation of a compulsory set of rules leading to objectiveness in the evaluation of data
- Reduction in the measuring uncertainty
- Improvement of the workflow through higher flexibility in the employment of the personnel
- Higher qualification of the personnel
- Transparent working processes

The combination of these effects lead to improved client orientation and higher quality of the testing result. It is furthermore expected that gaining accreditation for a laboratory and applying the principles of Kaizen will reduce the cost of performing test drives in the long run. It has been shown that the positive effects in the establishment of a quality management system by far outweigh the necessary effort, so the successful concept will be further extended by gaining accreditation for all testing laboratories within the department "Verification and Testing, Traction“ in the near future.

6. Bibliography
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