# A Distributed Computer System for Gauge Calibration

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*Abstract: Calibration is defined as a performance comparison against a standard of known accuracy. One can observe that manufacturing firms outsource their calibration activities to calibration services which are designed to manage the customer's entire calibration needs. In this paper a web-based system is described that allows the costumers to manage their calibration function on-line from their own personal computer. The users can access key calibration information even when they are under way using their laptop.*

*Keywords: gauge calibration, computer aided calibration, data collection, validation, data protection, access management*

## 1 Introduction

Regular calibration of the companies' gauges is a compulsory task in order to maintain traceability to the national and international standards. Hereby the comparability with result the measurements performed under similar conditions, at an other place, by an other gauge and an other operator.

One can observe, especially in the last years, that manufacturing firms outsource their supporting processes, those that are not part of the actual value addition process. In case of a quality management systems the regular calibration and the management of the gauges is a task, that can be made to a large extent independent from the other modules and therefore an appropriate choice for outsourcing.

A calibration service is designed to manage the customer's entire calibration needs from start to finish. This includes the logistics, record keeping and other administrative tasks as well. The service can be tailored to meet specific needs and is cost effective both for small and large companies.

Having a computer aided system in mind, the Internet provides for the required real-time communication, enabling the customers to place orders and to gain access to their own calibration data.

# 2 Functions of a Calibration Service

## 2.1 What Calibration Covers

As equipment and gauges undergoes changes in temperature or sustains mechanical stress and wear, critical performance gradually degrades. This called drift and, when it happens, the obtained test results become unreliable and both design and production may suffer. Drift can be detected and contained through calibration.

Calibration is defined as a performance comparison against a standard of known accuracy. It involves only the determination of the deviation from the nominal value, or includes adjustment to minimize the observed error. Properly calibrated gauges promote confidence in the manufactured products.

Calibration assures consistency, is fundamental to compliance with international and industry-sector specific standards and ensures that measurements are compatible with those made elsewhere.

Calibrations need to be done on a planned, periodic basis with evidence of the comparison results maintained. This record must include identification of the specific standards and method used and other test conditions. It should also be possible to demonstrate an unbroken chain of comparisons that ends at the agency responsible to maintain the country’s measurement standards. This linkage to the national standards, with known accuracy is called traceability.

When a calibration is performed, certificate is the end product and represents the only tangible evidence of the service. It not only shows the results obtained but the scope of testing and is a key means of judging the quality of the services provider.

## 2.2 Features of a Good Calibration Service

When selecting a calibration service the customers should consider the points listed below. This is necessary because the lack of regulation on calibration allows for a wide variance in the value of calibration.

- Extent of testing
- Information provided
- Measurement uncertainty
- Periodicity
- Speed
- Costs

Clearly the more thoroughly a gauge is tested, the greater the confidence is in it's measurement results. For mechanical measuring instruments recommendations are available for what parameters should be tested and at what points each parameter should be checked. However in some cases this is not adequate for determine a number of important properties of the instrument. A typical example is the recommendation for the Vernier calliper, where the recommended number of points does not give any information about the linearity of the gauge.

The information provided by the calibration service forms the basis for many decisions and so it is important that the customer gets this information and the information is accurate. Consequently it is desirable that the full data showing the gauges performance at each test point to be supplied with the calibration.

Measurement uncertainty is a way to express how good the calibration is. The uncertainty gives a clear indication whether the supplier has the technical capability to make the measurement. It is possible to review the best measurement uncertainty figures because this information is in the public domain of an accredited calibration laboratory.

Calibration periodicity is about how often a gauge should be calibrated. This is often a period of six months or one year. In order to assess whether this period can be overridden, two important pieces of information are needed:

- The calibration history of that particular gauge
- The application in which the gauge is used

One generally accepted algorithm is that if on three consecutive calibrations the gauge has remained within the specification, the period may be increased. Similarly if on two consecutive calibrations adjustment is required it should be reduced.

The second point is the risk. If the measurements made by the gauge are critical, it may be prudent to reduce the calibration interval. If both history and risk are considered and effective calibration periodicity can be maintained.

The next important factor is speed, because calibration usually means removing the gauge from doing the job and sending it to somewhere for calibration. Knowing that the equipment will be away for a certain period one can plan for that event, either by arranging for the use of a spare gauge or for a rental replacement. In case of common instruments, the service provider may take this arrangement for his or her own account. But if the promised period becomes more the cost might escalate and the control is lost. Companies that can provide on-site or overnight service have a competitive advantage.

By considering not only the fundamental service price, but looking at the service packages it is possible to reduce the less visible costs.

## 2.3 How Computers can Contribute

In order to determine what role computers can play in the calibration process let us first overview it from the placement of the order to delivery of the calibrated gauge with the calibration certificate. Let us assume that the customer in question is a registered customer already having an access code. First he puts an order for the calibration in the form of an gauge list, containing for each gauge it's identifier, name and measuring range. If the gauge is not yet registered in the database additional information requested, fully describing its main properties is.

The system maintains a list of calibration tasks to be performed together with their requested delivery dates. Using the information in that list, a proposed deadline is communicated to customer, together with the date when the gauge should be available for calibration. After accepting these conditions the actual scheduling of the calibration task will be performed. Each type of calibration task is allocated to a specific workplace. The operator of the calibration equipment at the specific workplace sees only the relevant part of the scheduling list.

The actual calibration process starts after the instrument to be calibrated has been delivered to the laboratory. First the gauges are checked for visible damages and cleaned. This is followed by keeping it for the prescribed period on a steel table in the air-conditioned room of the laboratory, together with the etalons to used in the calibration. When both gauge and etalons reached the prescribed temperature (20°C±1°C) calibration starts. The measurement results are noticed and in order to test data validity statistical calculations are done. In the possession of a valid set of measuring results a calibration certificate is issued containing all useful information: name and address of the customer, name and identifier of the gauge, measuring range, identifier and calibration certificate number of the etalon used in the calibration process, date of the calibration and name of the person who performed it. From the above mentioned data a record is kept in the laboratory. Finally the operator acknowledges the successful calibration of the selected gauge.

Before issuing the head of the laboratory controls the content of the certificate and after his approval it will be printed and signed.

Scheduling of the calibration tasks are done by the system automatically on a simple priority bases. In case of a conflicting situation decision is based on a set of rules.

All calibration data is kept and can be accessed by the customers through the Internet. They may retrieve previous as well as current measuring values or calibration certificates, analyse gauge history by appropriate statistical tools.

The operators are relived from a large portion of the administrative work and they are helped in doing statistical calculations for the sake of data validation. The less experienced operators are guided using a help function through the whole calibration process. If the customer request assistance for judging his gauge or in determining the calibration period a small built in rule-based expert system is at hand.

# 3 The System Structure

## 3.1 Hardware Structure

The calibration laboratory is equipped with the following measuring equipments: Heidenhain Certo 60, Etalon Polo length measuring machine and a Tesa-Visio 300 3D optical measuring machine.

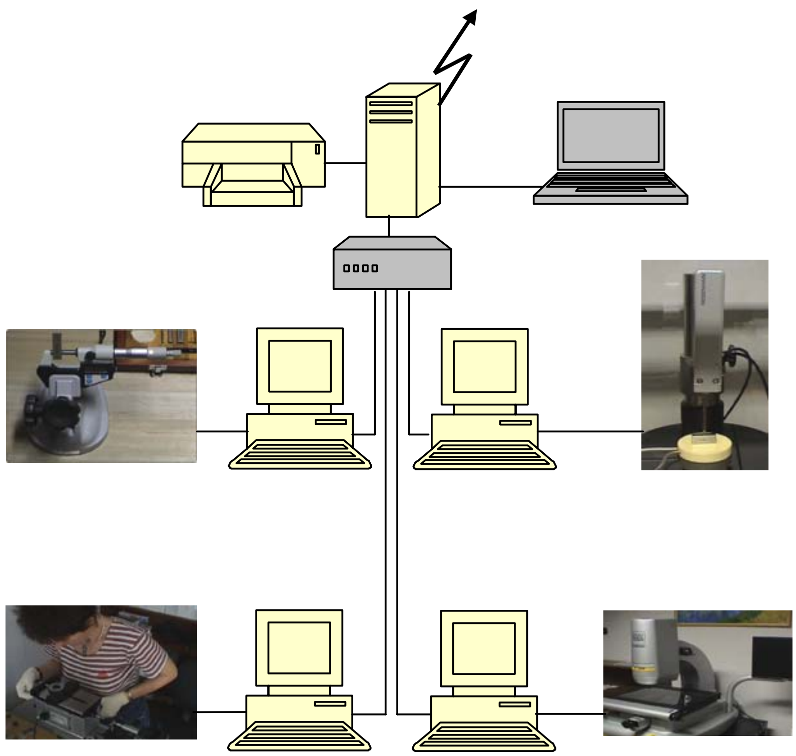

Figure 1
The hardware configuration of the calibration system

The equipments are interfaced to their control computer by manufacturer provided hardware and software. Hereby the factory established correction of the measuring values is maintained. Additionally a variety of laboratory grade etalons are available: a K-grade gauge block set, optical flats, angle gauges, granite square.

The computer network of the calibration laboratory, given in Figure 1, consists of a variety of workstations. These workstations serve as a data capturing unit for the measuring equipment attached and linked to the server through a switch.

A data collection unit registers in every fifth minute the temperature and humidity in the room. These values are saved on a daily base on the background store of the server.

## 3.2 Software Structure

### 3.2.1 The Database

The kernel of the software is a relational database. The contents of the main tables are described below. The table called *customers* contains records that hold all data relevant to that customer. The records have the following fields:

- **customer id** (primary key)
- Name of the customer
- Address of the customer (postal code, place name, street, number)
- Contact person
- Phone number
- Fax number
- E-mail address
- Payment (cash, bank transfer within 8, 15 or 30 days)

Records in the table *gauges* carry the following information:

- **customer id**
- **gauge id** (primary key)
- Gauge name
- Type
- Manufacturer
- Identifier
- Unit (of measurement)
- Output format (digital, analog)
- Measuring range
- Calibration procedure
- Resolution

- Power supply

Records in the calibration results table have the following fields:

- **gauge id**
- **calibration id**
- Calibration date
- Certificate number
- Certification date
- Name of the operator
- Approved by

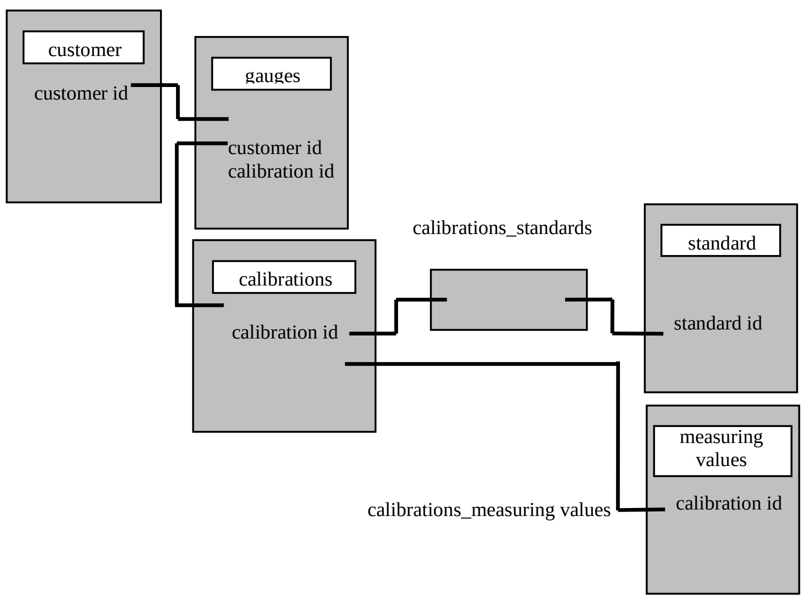


Figure 2
The structure of the database

The records in the measuring values table have the following entries:

- **measurement id** (primary key)
- **calibration id**
- Nominal value
- Actual values (6)

Information in the standards table is as it is listed below:

- **standard id** (primary key)
- **calibration id**
- Nominal value
- Calibration certificate number (standard)
- Date of the last calibration
- Uncertainty

### 3.2.2 The User Interface

The user interface is menu driven: at each stage of the calibration process adequate alternatives are posed to the user or appropriate frames for data input are displayed. At every point where measurement data is keyed in or enter through one of the available input channels validity is checked. This is an easy task because the nominal value is always available, so only an appropriate tolerance should be set. These tolerances can be determined in advance from standards and recommendations given by engineering bodies.

### 3.2.3 The Communication Software

The server is linked to the Internet using a broadband link (cable TV connection) providing a bandwith of 10 Mbits/sec. For sake of security the SSH protocol is used in the external communication. The workstations, as they are located close to the server are connected through conventional serial lines.

### 3.2.4 Information Security

Security is an important aspect; confidentiality, integrity and availability of the system should be maintained. Confidentiality means that the assets of the system are accessible only by authorized parties. Integrity means that assets can be modified only by authorized parties or only in authorized ways. Availability means that assets are accessible to authorized parties. In case of our database this can be broken down into the following requirements:

- Data base integrity
- Element integrity
- Auditability
- Access control
- User authentication
- Availability

Let us consider these aspects one by one: Data base integrity is maintained by using uninterruptible power supply, by mirroring the content of the database on an other background store, by saving content regular on an external device and keeping this medium on an other safe place.

Element integrity means the there correctness or accuracy. Ultimately, authorized users are responsible for putting correct data in the date base. However users make mistakes collecting data and entering values. Therefore a validity check is used to filter out rough errors. Measures should also be taken to prevent users to change calibration data after it has been approved, because in some cases they may act as evidence. For that purpose the records belonging to the specific calibration are 'frizzed'.

Sometimes it may be desirable to generate audit record of all access to the database. This can help in discovering malicious actions initiated either form inside or outside.

The data base is logically separated by user access privileges. In our case only the head of the laboratory is allowed to enter new customers in the system. Only a small portion of the related data can be seen by the operators. Also the invoices produced automatically by the system are confidential.

In the system a rigorous user authentication was built in. From the customers it requests a password which should be enough long and complex and changed regularly. In case of outside access the source address of the request is checked and validated. The operators also undergo a time-of-day check.

Availability means a more or less continuous operation servicing the user requests. It means that the system should consist of high reliability modules and should have enough redundancy. In our case a dual processor system with hard disk mirroring provides the required reliability.

# 4 Implementation

## 4.1 Overview of the Calibration Procedures

The calibration procedures have been formulated according to the guidance of the National Accreditation Body. They describe step by step the operations performed during the calibration and each critical step is illustrated by an explaining picture. The procedure assigns the appropriate standard from the list to the calibration task in question.

### 4.2 Software Implementation

The system is implemented on an IBM compatible PC with 1MByte RAM and two 160 GByte background store running LINUX operating system. The database is implemented by using mySQL and access is provided by Apache web server. The user interface was implemented in PHP.

## 5 Operational Experiences

The beta version was tested by a number of selected users for three months in continuous operation. During this period no down time longer then 15 minutes was encountered and no loss of data was experienced. The menus in the human interface proved to self explaining and they were well received by the users. The help system provided for the calibration personal is a good guidance for the less experienced.

**Conclusions**

The introduction of an integrated system improved the quality of the service and the throughput of the laboratory. At the same time it released the customers from the housekeeping work related to the maintenance of calibration data. Both in-house users and customers became acquainted with the system easily and accepted after a short period of time. The results gained during test period came up to our expectations.

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