

CONCEPTION OF A HIGH PRECISION MEASUREMENT ROOM

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Abstract: The aim of a high precision measurement room is to minimize most of the disturbing influences on the measuring devices installed in the measurement room by structural organization. The goal of scientific research in the field of manufacturing metrology is in particular the improvement of the measurement accuracy in the micro- and sub-micrometer range with simultaneously desired automation of the measurement procedures. In each case, reliable results must be obtained according to the internationally defined units for the success of the research work and for the acknowledgement of the results in the professional world. This is only possible under most extensive exclusion of the disturbing environmental influences in a measurement room of highest grade, which is particularly shielded and kept at constant temperature.

Keywords: measurement room, precision dimensional measurement, air conditioning

1 INTRODUCTION

Each measurement result is joined by deviations. Both the result's value and the uncertainty of measurement depend on a huge number of influences. Substantially, these influences are caused by the measuring instrument, the workpiece, the operator and the environment. The ratio between deviations caused by environment and measuring instrument is approximately 10:1 [1]. Therefore, highest requirements regarding the minimization of environmental influences are necessary to fulfill research tasks in the field of manufacturing metrology or precise measurements. Scientific realizations or precise measurements will only be accepted by experts if the predications are reliable or the measurement results are restorable [2]. This is given if the environmental conditions are documented during the moment of measuring. In consequence, the main task of a measurement room is to minimize influences by the environment and to keep them on a well-known, constant level.

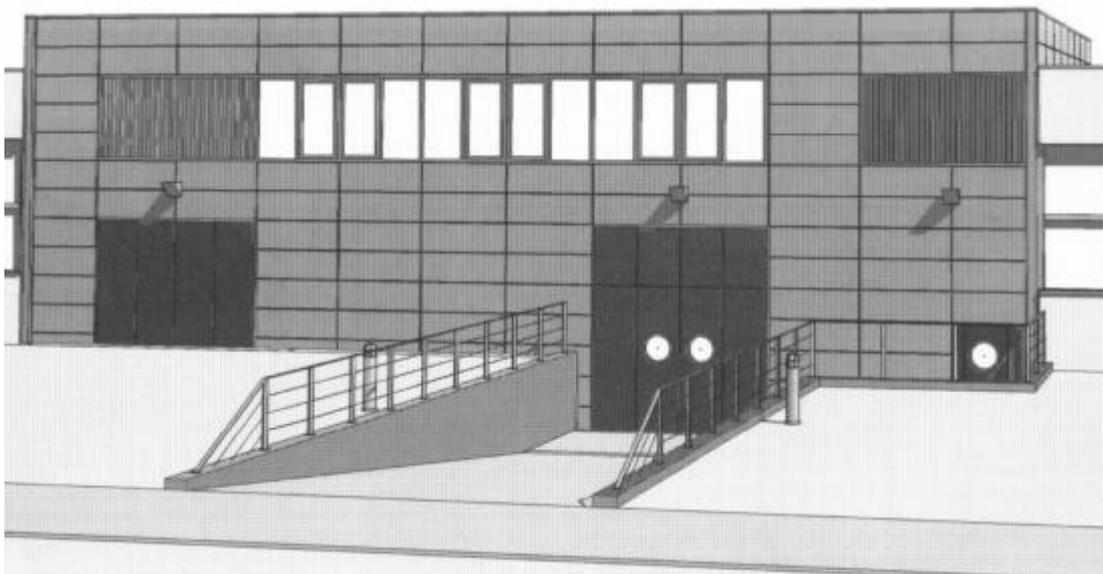


Figure 1. The new measurement room building of the University Erlangen-Nuremberg, Chair Quality Management and Manufacturing Metrology

The most important environmental measurement influences are:

- temperature (thermal conduction, convection and radiation)
- vibrations
- humidity
- pollution

The structural organization of a measurement room ensures that most of these disturbing influences will be reduced and kept constant. Some recommendations relating to the conception of measurement rooms are given in VDI/VDE 2627 [3], but only partially fit the requirements of a high precision measurement room. The new high precision measurement room of the University Erlangen-Nuremberg demonstrates the demands for such a building and features of technical realization.

2 CONCEPTION OF A HIGH PRECISION MEASUREMENT ROOM

The aim for planning a high precision measurement room is to minimize by structural organization most of the disturbing influences on the measuring instruments installed in the measurement room and the measuring process. The Chair Quality Management and Manufacturing Metrology as the user of the building describes the requirements regarding the environmental conditions in consideration of the accuracy of the instruments and the future measuring tasks as a base for all further planning.

Table 1. Requirements regarding the environmental conditions of the new measurement room of the University Erlangen-Nuremberg

Characteristic	Requirements
Dimensions	
length	13,2 m
width	8,0 m
height	5,9 m
area	110 m ²
Volume	623,0 m ³
Air circulation ratio per hour	17
Percentage of fresh air	5% - 10%
Base Temperature	20°C ± 0,1 °C
Operating temperature range	18 - 25 °C
Allowable temporal temperature deviations	
DT during 1h	0,1 K
24h	0,3 K
Allowable spatial temperature difference	
DT per 1m	0,1 K
totally	0,5 K

First step towards the conception of a measurement room is the search and selection of an optimal location for the building which is oriented to aspired uncertainty of future measuring tasks. With extensive investigations and ground-analysis on vibrations, the suitability of the planned location was acknowledged. In addition, the loose sandy soil at the location makes a flexibly stored foundation of the measurement building redundant. The reinforced concrete base plate of the actual measurement room with a thickness of 1 meter is isolated from the ground only by a mineral material insulating layer for the avoidance of thermal conduction. A seam around the base plate prevents direct contact to the remaining foundation of the measurement room building and in such a manner it also prevents a transfer of building oscillations through the base plate on the installed measurement devices [4].

The function of the air conditioning system is to keep the measurement room at a basic temperature within the given limits spatially and temporally during operation. For later operation, the air conditioning system must be qualified to compensate thermal interference and minimize spatial temperature gradients. The basis for planning and dimensioning the air conditioning system results from an exact analysis of all expected interferences. From the beginning, suitably choices of constructional measures might reduce or weaken those influences.

The measurement room is protected against thermal interference with state of the art technology. Electrical heating conductors in the neutral fiber of the base plate let the temperature of the floor remain accurately at the given base temperature. The thermal input due to the lights is minimized by

an additional air exhaust in the light-system of the dome lamps. Inside the measurement room, the walls are covered with hollow section metal elements, which are equipped with rectangular openings towards the inside of the measurement room. The air will be fed back to the air conditioning through these openings. The exhausted air warms up the wall panels up to the basic temperature and isolates them from the colder main construction walls. The external walls are thermally isolated by mineral material insulating layers.

To remove a local, intermittent heat load the measurement room is divided into four quadrants, and the middle temperature in each of these quadrants will be recorded by Pt-100 double sensors. The air conditioning system is conceived that each quadrant can be regulated independently. With a room height of 5.90 meters a considerable space volume of 623 m³ is available, which additionally absorbs temporary thermal interferences. The large room height enables a good mixture of the turbulent injected air.

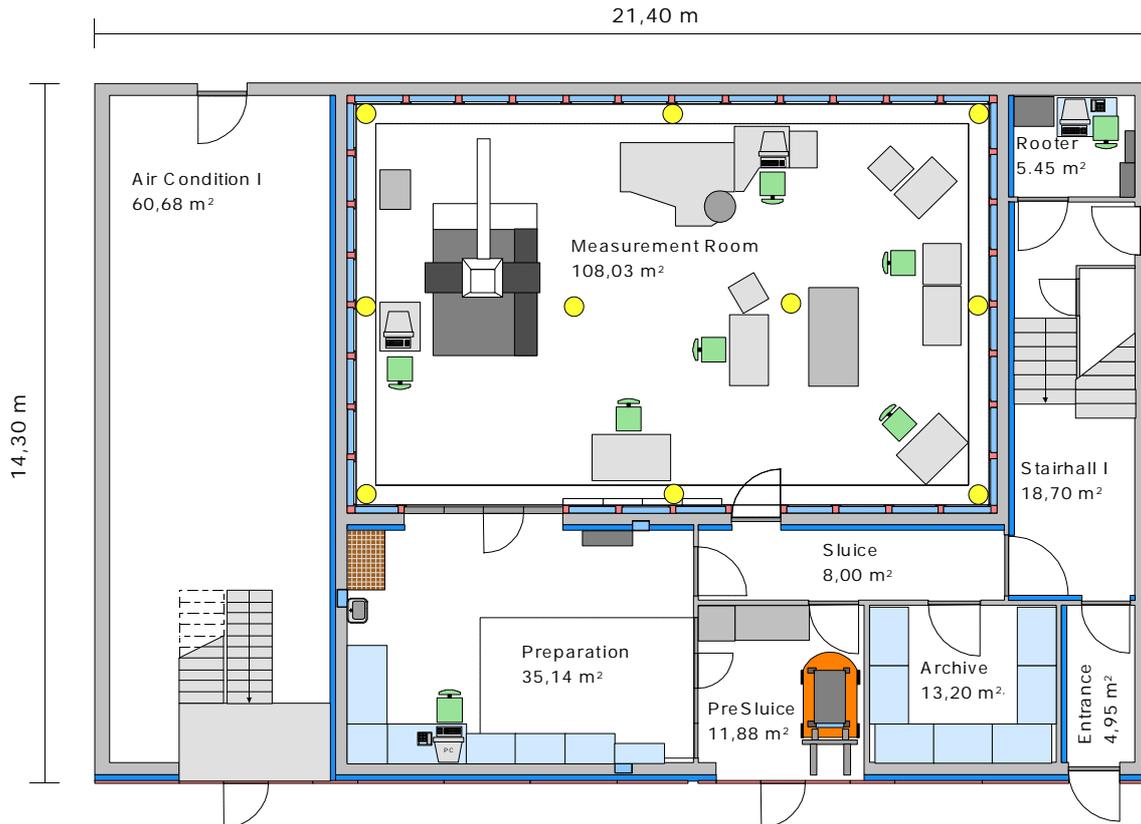


Figure 2. Basement of the measurement room building of the University Erlangen-Nuremberg

Because of temporally different temperature levels which may occur within the four-quadrant conception, a strict temperature plausibility check is necessary. The application of Pt-100 double sensors permits a mutual alignment and avoids an unwanted automatic controller action of the climatic-technical system with malfunctions of the temperature entry. With an uncertainty of ± 1 mK and a resolution of 0.1 mK the assigned resistance of the temperature measuring bridge enables an uncertainty of the entire temperature measuring chain less than 0,01 K and thereby fulfills all requests regarding the spatial and temporary temperature stability.

3 DESCRIPTION OF THE AIR-CONDITIONING SYSTEM

To obtain reliable measurement results a climate with defined values for temperature, humidity, air pressure, air speed and particles is necessary. It is task of a air conditioning system to heat, cool, humidify, dry, filter and circulate the air [5]. A lot of factors are to be taken into account while laying out an air conditioning system. Figure 3 shows a rough order of these factors.

Some examples for these factors for the measurement room are displayed here: the average total thermal output of the installed instruments including the operators was estimated with 10 kW (to minimize thermal fluctuations all thermal loads will be kept running); the external climate for summer time was defined with an average temperature of 32 °C and a relative humidity of 40%, for winter time is was defined with an average temperature of -12 °C and a relative humidity of 80%.

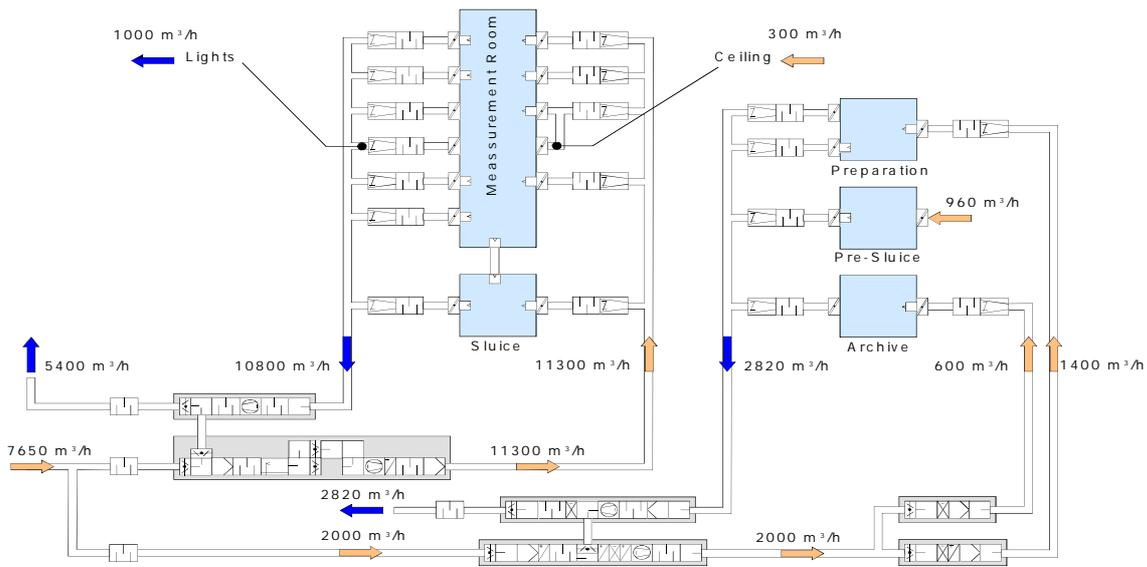


Figure 3. Structure of the air conditioning system

ISO 1 defines the reference temperature to be 20°C [6]. Normally, the air conditioning system of a measurement room is planned for a fixed operating point which is equal to the reference temperature. The air conditioning system of the considered measurement room can work at any operating point in the range between 18 °C and 25°C. In the future, this enables the investigation of different ways for economizing the energy and running costs and protecting the investment against changes in standards which were fundamental when planning the air conditioning system. For this purpose, a lot of parameters of the air conditioning system i.e. heating and cooling capacity, airflow rate, cross section of outlets must be variable. The system must be capable of ensuring the required characteristics both in the cooling and in the heating mode. For this reason, the chosen operating point will always be reached from the same direction. The ingoing air as a mixture of fresh air from outside and circulated air from the measurement room will first be cooled down to a temperature of 5 °C and then heated up in two steps to the demanded temperature of the operating point. To ensure an ideal mixture of the air in the entire measurement room in the heating mode, the ingoing air will be blown in by radial fans and the outgoing air exhausted also by radial fans. The quantity of the ingoing air is more than the quantity of outgoing air. This causes a slight overpressure of about 10 Pa in the measurement room, which prevents the irruption of unfiltered and unconditioned air when doors are opened. The aim of the already mentioned monitoring in 4 zones is to compensate local dispersions of cool load (e.g. caused by a group of people) as well as to generate well defined temperature gradients in the space. Based on these generated temperature gradients, the behaviour of measuring instruments can be analysed. Manipulating variables are the volume flow of the ingoing and outgoing air. The air flow volumes can be controlled separately in each quadrant of the measurement room. The desired air quantities can be set up either dynamically by changing the number of revolutions of the radial fans or statically by changing the cross section of the ingoing and outgoing air feeder. With respect to the comfortable feeling of the operators in the measurement room, the mean air velocity should not exceed 0,2 m/s. Accordingly, the air changing rate has a value of 17 per hour. To achieve an optimal intermixture of the room air for these low level values, the ingoing air is blown in through twisted inlets. In other comparable measurement rooms the air is blown in laminar through the ceiling and the floor.

4 BENEFITS FOR RESEARCH WORK

Normally, air conditioning systems in measurement rooms are calculated for a fixed, given operating point. Apart from the described four-zone regulation a further remarkable property of the air conditioning system is to be pointed out. As a special feature, the system guarantees the required temperature characteristic values at a basic temperature freely eligible in the interval from 18 °C to 25 °C. Future research work in the measurement room will thus lead to a reduction of measurement uncertainty by including investigations of the temperature influences on measurement devices and results of measurement.

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