ECN

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# UPWIND METROLOGY

## Deliverable D 1A2.2

## Metrology Database - Definition


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## Abstract

The UPWIND project is a European research project that focuses on the necessary up-scaling of wind energy in 2020. Among the problems that hinder the development of wind energy are measurement problems. For example: to experimentally confirm a theoretical improvement in energy production of a few percent of a new design by field experiments is very hard to almost impossible. As long as convincing field tests have not confirmed the actual improvement, the industry will not invest much to change the turbine design. This is an example that clarifies why the development of wind energy is hindered by metrology problems (measurement problems). Other examples are in the fields of:

- Warranty performance measurements
- Improvement of aerodynamic codes
- Assessment of wind resources

In general terms the uncertainties of the testing techniques and methods are typically much higher than the requirements. Since this problem covers many areas of wind energy, the work package is defined as a crosscutting activity.

The objectives of the metrology work package are to develop metrology tools in wind energy to significantly enhance the quality of measurement and testing techniques. The first deliverable was to perform a state of the art assessment to identify all relevant measurands. The required accuracies and required sampling frequencies have been identified from the perspective of the users of the data (the other work packages in UPWIND).

The work performed has led to the definition of a database of measurement instruments. The list of parameters is an important table in the database, where a list of state-of-the-art analysis techniques, a list of state-of-the-art measurement techniques, a sensor list and a list of commercially available sensors. Especially the many relations between all parameters are valuable additions to the database. The Metrology Database is a valuable tool for the further assessment and interest has been shown from other work packages, such as Training.

This report describes the structure of the database and instructions how to use it. The Metrology Database will be made available on the UpWind Website to the partners in the project.

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# 1. Introduction

**The UpWind project**
UpWind is a European project funded under the EU's Sixth Framework Programme (FP6). The project looks towards the wind power of tomorrow, more precisely towards the design of very large wind turbines (8-10MW), both onshore and offshore. Furthermore, the research also focuses on the requirements to the wind energy technology of 20MW wind turbines.
The challenges inherent to the creation of wind farms of several hundreds MW request the highest possible standards in design, complete understanding of external design conditions, the design of materials with extreme strength to mass ratios and advanced control and measuring systems geared towards the highest degree of reliability, and critically, reduced overall turbine mass.
The wind turbines of the future necessitate the re-evaluation of the turbine itself for its reconception to cope with future challenges. The aim of the project is to develop accurate, verified tools and component concepts that the industry needs to design and manufacture this new type of turbine. UpWind focuses on design tools for the complete range of turbine components. It addresses the aerodynamic, aero-elastic, structural and material design of rotors. Critical analyses of drive train components will be carried out in the search for breakthrough solutions. The UpWind consortium, composed of over 40 partners, brings together the most advanced European specialists of the wind industry.

**Expected results**
In the UpWind project research will lead to accurate, verified tools and some essential component concepts the industry needs to design and manufacture the new breed of very large wind turbines. Among others, UpWind will address the aerodynamic, aero-elastic, structural and material design aspects of rotors. Future wind turbine rotors may have diameters of over 150 meters. These dimensions are such that the flow in the rotor plane is non-uniform as a result of which the inflow may vary considerably over the rotor blade. Full blade pitch control would no longer be sufficient. That is why UpWind will investigate local flow control along the blades, for instance by varying the local profile shape. New control strategies and new control elements must be developed and critical analyses of drive train components must be carried out in the search for breakthrough solutions.
Furthermore, wind turbines are highly non-linear, reactive machines operating under stochastic external conditions. Extreme conditions may have an impact a thousand times more demanding on, for instance, the mechanical loading than average conditions require. Understanding profoundly these external conditions is of the utmost importance in the design of a wind turbine structure with safety margins as small as possible in order to realise maximum cost reductions.
A similar argument applies to the response of the structure to external excitations. In order to make significant progress in this field, more accurate, linearly responding measuring sensors and associated software are needed. Preferably, the sensors should remain stable and accurate during a considerable part of the operational lifetime of a wind turbine. UpWind will explore measuring methods and will look more in detail into new remote sensing techniques for measuring wind velocities. The validation and verification of the analyses, tools and techniques depend on reliable and appropriate measurements. The task of the work package ‘Metrology’ is to identify the critical issues in measurement techniques and to find solutions for the most critical ones.

More information on the UpWind project is found on the website:
www.upwind.eu

## 1.1 Work Package 1A2 Metrology

As the project includes many scientific disciplines which need to be integrated in order to arrive at specific design methods, new materials, components and concepts, the project's organisation structure is based on work packages which variously deal with scientific research, the integration of scientific results, and their integration into technical solutions. Since the measurement problems are related to several areas in the wind energy, the work package Metrology is defined as an integrating work package.

The metrology problems to develop wind turbine technology are the focus of this work package since the development of wind energy is hindered by measurement problems. In particular the fluctuating wind speed introduces large uncertainties and these fluctuations in the wind are experienced throughout the entire wind turbine. An example of a problem through measurement uncertainties is that it is almost impossible to confirm anticipated small performance improvements resulting from design modifications by means of field tests. As long as convincing field tests have not confirmed the actual improvement, the industry will be hesitant in investing in turbine design improvements. Furthermore, the developments within the UpWind project will require validation that is based on reliable and appropriate measurements.

The objective of the metrology work package is to develop metrology tools in wind energy to significantly enhance the quality of measurement and testing techniques. The first deliverable has been published being the first step to reach this objective and the list of parameters that should be measured in wind energy. The list has been developed in close collaboration with the other UpWind project work packages. The second deliverable is to find theoretical solutions for the identified metrology problems. Based on the deliverable 1, the list of measurement problems, it has been analysed what the precise consequences of the identified problems are and in which directions possible solutions can be found.

In order to process the large amounts of data, where there are many relations, a database structure has been designed. A dedicated Metrology Database is designed to substitute the different MS-Excel sheets generated in Task 1. The database has been developed in MySQL, which can be installed on both Linux and MS-Windows personal computers. The metrology database consists of a number of individual tables, which are linked together through a number of variables. The applications from the different UPWIND Work Packages have been used at the key parameters and the other tables contain the derived and necessary methods, measurands, techniques, etc.

## 1.2 How to read this report

The development of metrology tools to significantly enhance the quality of measurement and testing techniques in wind energy is carried out in three steps. These steps are described in the work programme and are defined as deliverables. The three steps (deliverables) are:

1. Problem identification: determination of the parameters that must be measured for the various problems encountered in wind energy and the required accuracies.
2. Available techniques and theoretical solutions: for the identified parameters the state-of-the-art measurement techniques are described, the problems that may be encountered are described and possible theoretical solutions are presented.
3. The practical value of the proposed solutions is demonstrated.

In this report the structure of the Metrology Database is described. The database is available to the UpWind partners through the UpWind website. Since the contents of the database change while working in the project, these are not described in this report.

# 2. Structure of the Metrology Database

The Metrology Database is defined to structuring all topics relating to metrology. The implemented dedicated database consists of a number of inter-related tables. This Chapter describes the tables and their interrelation together with a small tutorial on how to open the database.

## 2.1 Introduction

A dedicated database has been designed to substitute the large number of MS-Excel sheets used during the initial project definition period. The database has been designed in OpenSource software package, named MySQL®, which is compatible with MS-Windows and Linux computers.
The metrology database consists of a number of individual tables, which are linked together through a number of variables. The applications, defined in the other UPWIND Work Packages during the integration process, have been defined as key parameters and the tables contains a registration of methods, problems, references, measurands, techniques, sensors and commercial sensors.
It has been of great importance to use the cross references defined in database between applications, methods, parameters and sensors during the process of identifying problems between the state-of-art-analysis-technique and the state-of-art-technique.

## 2.2 Database structure

The metrology database consists of 11 tables, where the structure and contents of each table is defined in the sections below. The main tables are connected as shown on Figure 1, the remaining tables contain additional information.

The database structure and the contents of the tables represent three different aspects:
1) Application types.
2) State-of-art-analysis-techniques, derived problems and documentation.
3) Identification of measurands and the state-of-art-technology.

The database furthermore includes tables with sensor types, available sensors and links to sensor information.

# Metrology database structure

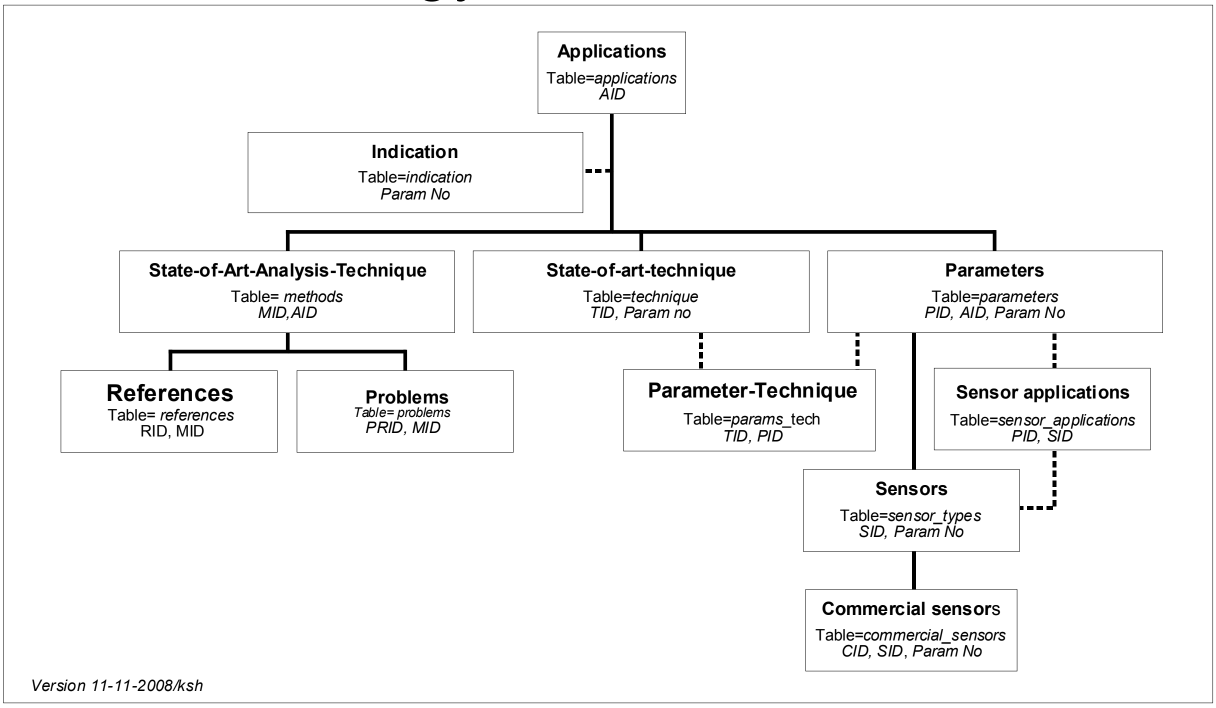


Figure 2.1 *Structure of the metrology database.*

Table 2.1 *Summary of ID parameters used in the metrology database.*

| ***Parameters*** | ***Definitions*** |
|---|---|
| **AID** | Definition of application ID |
| **CID** | Commercial sensor ID |
| **CRID** | Commercial sensor reference ID |
| **MID** | State-of-art-analysis-technique ID |
| **Param No** | Indication of parameter location ID |
| **PID** | Parameter ID, referring to a physical parameter |
| **PRID** | Problem ID, referring to a method |
| **RID** | Reference ID, referring to method description |
| **SID** | Sensor type ID, referring to a principle |
| **TID** | State-of-art-technique ID |

Detailed definitions of each table structure are listed in Appendix A.

Table 2.2 *Parameter cross references for all tables.*

| Tables | AID | CID | CRID | MID | Param No | PID | PRID | RID | SID | TID |
|---|---|---|---|---|---|---|---|---|---|---|
| Applications | X | | | | | | | | | |
| Indication | | | | | X | | | | | |
| Methods | X | | | X | | | | | | |
| Technique | | | | | X | | | | | X |
| Parameters | X | | | | X | X | | | | |
| References | | | | X | | | | X | | |
| Problems | | | | X | | | X | | | |
| Sensor applications | | | | | | X | | | X | |
| *Sensor types* | | | | | X | | | | X | |
| *Commercial sensors* | | X | | | X | | | | X | |
| *Data sheet* | | X | X | | | | | | | |

The application definition table contains information about different applications as listed in Appendix A.

## 2.3 Access to the database

The database has been developed on a database-server located at DTU, Lyngby. During the process of the UpWind project the database is a prototype and is continuously being updated. User access information is presented in the Table below.

Table 2.3 *Driver information to access the Metrology database through ODBC.*

| DRIVER (MS-Windows XP): | MySQL ODBC 3.51 Driver |
|---|---|
| Database-server IP: | 130.226.17.201 |
| Port (default): | 3306 |
| Database name: | Metrologi |
| User name (UID): | |
| Password (PWD): | |

User names (UID's) and Passwords (PWD's) will be distributed when the database is ready for release. The ODBC 3.51 driver is used to access MySQL® version 4.0 and different commercial and freeware tools can be used to access the database:

Table 2.4 *Tools for accessing the Metrology database.*

| ***Tool*** | ***Note*** |
|---|---|
| MySQl® Control center | Based on SQL scripts |
| MySQL® Query Builder | Based on SQL scripts |
| MS-Excel® | Requires an ODBC installation of MySQL® ODBC 3.51 Driver |
| MS-Access® | Requires an ODBC installation of MySQL® ODBC 3.51 Driver |
| MS-Word® | Requires an ODBC installation of MySQL® ODBC 3.51 Driver |

Using MS-Access with linked MySQL® tables enables the user to work in a MS-Access environment but requires access to the Internet. MS-Access® includes all necessary tools for querying and reporting the contents of the database. A MS-Excel link enables import of table(s) or queries to a MS-spreadsheet.

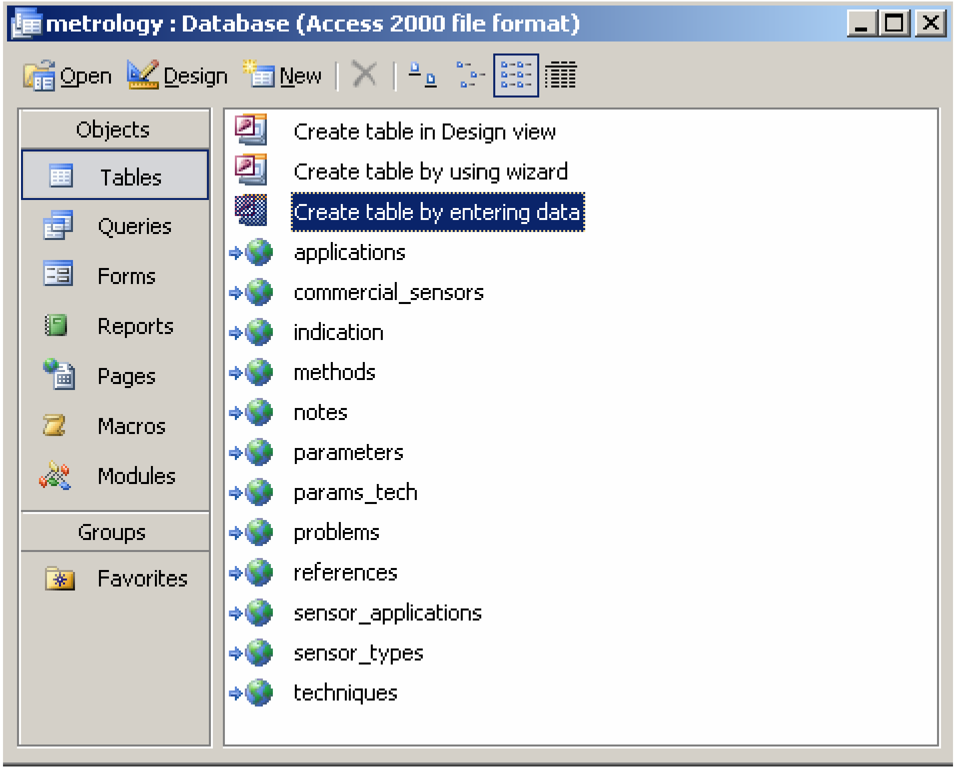


Figure 2.2 *List of linked tables in MS-Access from the Metrology database.*

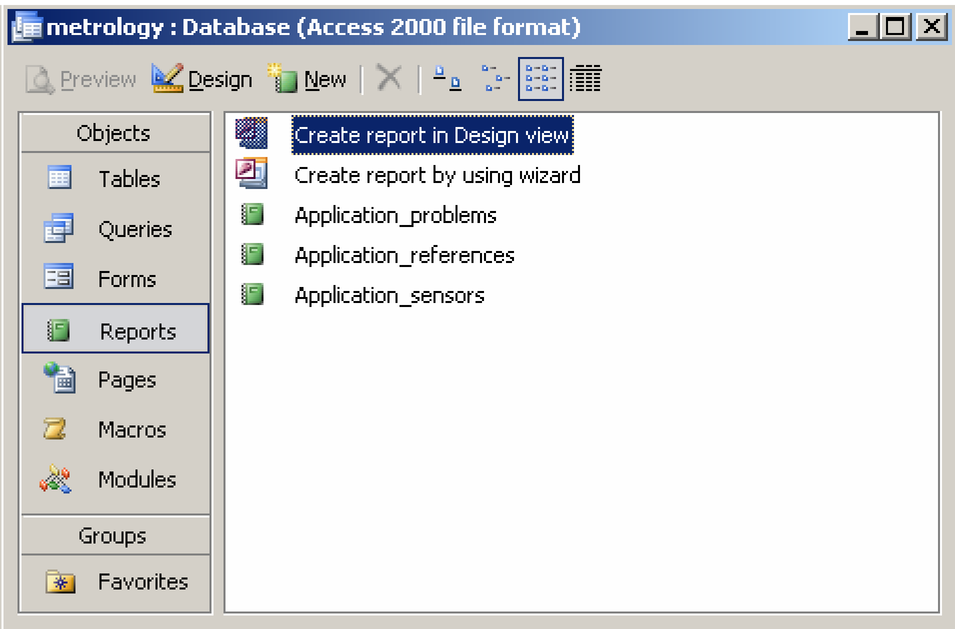


Figure 2.3 *List of predefined, dedicated reports based on linked tables.*

# 3. Discussion and Conclusions

The UpWind consortium research covers a wide area of expertise in wind energy. The required measurement and analysis techniques covering this wide range are identified after successful and extensive interaction between the various work packages of the UpWind project.

The second deliverable is to find theoretical solutions for the identified metrology problems. Based on the deliverable 1, the list of measurement problems, it has been analysed what the precise consequences are of the identified problems and in which directions possible solutions can be found.

In order to process the large amounts of data, and especially the many relations, a database structure has been designed. A dedicated database is designed to systematically organise the information that has been generated. First of all, the identified measurement problems are included, the state-of-the-art measurement techniques, including lists of sensors applied to measure the various measurands. Furthermore, a list of commercially available sensors is included.

The database has been developed in MySQL, which can be installed on both Linux and MS-Windows personal computers. The metrology database consists of a number of individual tables, which are linked together through a number of variables. The applications from the different UPWIND Work Packages have been used as key parameters and the other tables contain the derived and necessary methods, measurands, techniques, etc.

Further work within the work package 1A2 Metrology will concentrate on the further analyses and demonstration of the measurement techniques and analysis techniques.

# Appendix A Structure of the tables

## A.1 Applications

The ‘Applications’ table, lists and identifies possible applications for which the measurements are required, like power performance, or other UpWind work packages.

Table A.1 *Definition of table ‘Applications’*

| **Field** | **Type** | **Null** | **Definitions** |
|---|---|---|---|
| ***AID*** | smallint(6) | No | Application ID |
| WP | float | No | UPWIND Work pakages reference |
| Description | longtext | No | Descriprion |
| Comments | longtext | No | Additionals |

## A.2 State-of-art technique

Different state-of-art-techniques refer to the different types of physical parameters which are needed; e.g. 1D wind speed can be measured with different techniques like a cup, ultra sonic or propeller anemometers. A representative number of techniques currently in operation have been listed with reference to the required sensors.

Table A.2 *Definition of table ‘State-of-art Techniques’*

| **Field** | **Type** | **Null** | **Definitions** |
|---|---|---|---|
| ***TID*** | smallint(6) | No | Technique ID |
| Param-no | varchar(4) | No | Reference number |
| Signal | varchar(40) | No | Signal type |
| State-of-art-tech | longtext | No | Description |
| Remarks | longtext | No | Remarks |
| Accuracy | varchar(20) | No | |

## A.3 State-of-art-analysis-technique

The ‘State-of-art-analysis-technique’ table is named ‘Methods’ contains a list of applicable methods used currently in wind energy with reference to current standards and the necessary parameters. Please note that problems associated to each method are listed in table: ‘Problems’.

Table A.3 *Definition of table ‘Methods’*

| **Field** | **Type** | **Null** | **Definitions** |
|---|---|---|---|
| ***MID*** | smallint(6) | No | Methods ID |
| AID | smallint(6) | No | Application ID |
| Standard | varchar(20) | No | Reference to standard |
| Output | longtext | No | Typical output |
| Method | longtext | No | Description of method |

## A.4 Problems

The previous table ‘Methods’ contains a list of applicable methods used currently in wind energy community with reference to standards and necessary parameters. A number of problems associated to each of these methods have been identified and included in the ‘Problems’ table.

Table A.4 *Definition of table ‘Problems’*

| **Field** | **Type** | **Null** | **Definitions** |
|---|---|---|---|
| ***PRID*** | smallint(6) | No | Problem ID |
| MID | smallint(6) | No | Application ID |
| Problems | Longtext | No | Definition of problems |
| Improvements | Longtext | No | |
| Actions | Longtext | No | |

## A.5 Parameters

The measurement parameters represent all required (needed) parameters used in different wind turbine related applications defined in the UpWind Work Packages.

Table A.5 *Definition of table ‘Parameters’*

| **Field** | **Type** | **Null** | **Definition** |
|---|---|---|---|
| ***PID*** | smallint(6) | No | Parameter ID |
| AID | smallint(6) | No | Application ID |
| Param-no | smallint(6) | No | Reference number |
| Signal | longtext | No | Signal description |
| Unit | varchar(20) | No | |
| Desired-accuracy | varchar(20) | No | |
| Traceable | char(2) | No | |
| Sampling-frequency-range | longtext | No | |
| Required | char(2) | No | |
| Measurement-position | longtext | No | |
| Note-id | smallint(6) | No | Reference to Note ID |

## A.6 Notes

The table contains all notes given in the previous tables.

Table A.6 *Definition of table ‘Notes’*

| **Field** | **Type** | **Null** | **Definition** |
|---|---|---|---|
| ***Note-id*** | smallint(6) | No | Note ID |
| Comment | longtext | No | |

## A.7 Sensors

All different sensor types applicable for measuring the needed parameters are defined with reference to the parameters.

Table A.7 *Definition of table 'Sensor types'*

| **Field** | **Type** | **Null** | **Description** |
|---|---|---|---|
| ***SID*** | smallint(6) | No | Sensor ID |
| Technique | longtext | No | Description of State-of-art technique |
| Type | varchar(20) | No | |
| Influence parameters | varchar(20) | No | |
| Accuracy | varchar(20) | No | |
| Operational conditions | longtext | No | |
| Freq-response | varchar(20) | No | |
| Typ-application | longtext | No | |
| Tracebility | char(2) | No | |
| Manufacurer | varchar(40) | No | |
| Advantages | longtext | No | |
| Dis-advantages | longtext | No | |

## A.8 Commercial sensors

Commercial available sensors including accuracy and traceability are listed in the table named 'Commercial Sensors'. Where possible, operational characteristics from the experienced experimenters are included in this table.

Table A.8 *Definition of table 'Commercial sensors'*

| **Field** | **Type** | **Null** | **Definition** |
|---|---|---|---|
| ***CID*** | smallint(6) | No | Commercial sensor ID |
| ***SID*** | smallint(6) | No | |
| Param-no | varchar(4) | No | |
| State-art-tech | varchar(20) | No | |
| Type | varchar(40) | No | |
| Make and id | varchar(40) | No | |
| Accuracy | varchar(20) | No | |
| Freq-response | varchar(20) | No | |
| Comments | longtext | No | |
| Links | longtext | No | Manufacturers specifications |

## A.9 Technique-Parameters

The table contains cross-references between the records in the 'technique' table and the parameters from the 'parameters' table.

Table A.9 *Definition of table 'params-tech'*

| Field | Type | Null | Definition |
|---|---|---|---|
| ***TID*** | smallint(6) | No | Technique ID |
| ***PID*** | smallint(6) | No | Parameter ID |

## A.10 Sensor applications

The table contains cross-references between the records in the table 'parameters' and sensor types in the table named 'sensor types'.

Table A.10 *Definition of table 'Sensor applications'*

| Field | Type | Null | Definition |
|---|---|---|---|
| ***PID*** | smallint(6) | No | Parameter ID |
| ***SID*** | smallint(6) | No | Sensor ID |

## A.11 Indication

The table contains a reference to the list of main topics based on 'Param No'.

Table A.11 *Definition of table 'Indications'*

| Field | Type | Null | Definition |
|---|---|---|---|
| ***Param-no*** | Type | Null | Default |
| ***Indication*** | Varchar(50) | No | Reference to possible application area. |
| ***Note_id*** | Smallint(6) | No | |

## A.12 References

The table contains a description of the available references to the methods listed in the 'Method' table.

Table A.12 *Definition of table 'References'*

| Field | Type | Null | Definition |
|---|---|---|---|
| ***RID*** | smallint(6) | No | Reference ID |
| ***MID*** | smallint(6) | No | Method ID |
| ***Reference*** | Longtext | No | Scientific reference |
| ***Name*** | Longtext | No | |
| ***Description*** | Longtext | No | Short |
| ***Comment*** | Longtext | No | |