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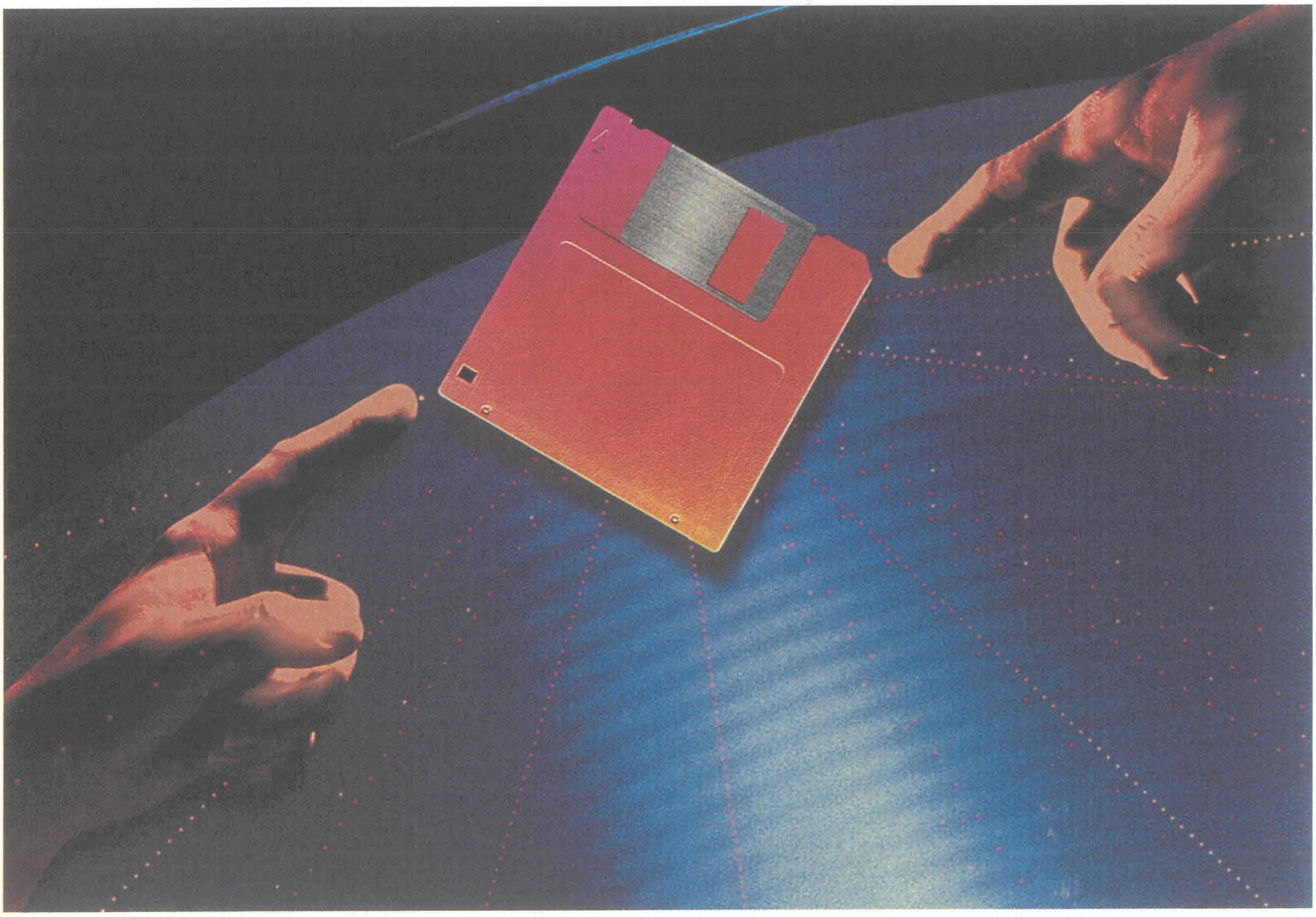

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Software applications in the field of metrology

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SOFTWARE VERIFICATION FOR MEASURING INSTRUMENTS

A EUROPEAN APPROACH (PAGE 5)

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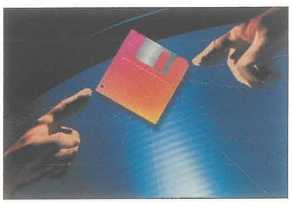

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Editorial

Software applications in legal metrology

Modern measurement technology is characterized by the progressively generalized use of sophisticated microelectronic devices, data processing and interfaces to accomplish data flow transfers.

This technology is playing an increasingly important role in numerous fields of measurement, and opens up whole new possibilities such as:

- obtaining more reliable measuring results by introducing built-in electronic checking facilities which come into play when significant faults are detected;
- connecting measuring instruments both to each other and to computers in order to manage production lines, produce invoices or statistics and, in general, keep check on processes either with a minimum number of staff or even automatically, night and day, without the need for any operator supervision.

The problem facing legal metrology is to allow the usage and flexibility of these "intelligent" devices, whether they be incorporated in instruments or modular measuring systems fully or partially under legal control, whilst still maintaining sufficient protection against unauthorized changes of legally related functions.

This was clearly demonstrated by Dr. R. Schwartz (PTB, Germany) in his article *Software interfaces and requirements for free-programmable nonautomatic weighing instruments* which was published in the January 1996 issue of the OIML Bulletin.

Moreover, an important challenge in the future for OIML is to ensure the harmonized examination of free-programmable instrument patterns submitted for approval, i.e. a uniform interpretation with regard to software examination and documentation.

It may be that for certain categories of instruments or applications, it would be inadvisable to authorize the free-programming of these instruments by the users themselves; as a general rule certain parts of the software which directly concern the measurement result should be protected or "sealed" so as to only authorize access to those functions which are *not* under legal control.

These problems should be considered by the respective OIML technical committees and subcommittees when the Recommendations for which they have responsibility are under review.

In this issue of the Bulletin we present an article which summarizes the European approach to software verification for measuring instruments. This paper was prepared by a working group mandated by the European Commission which considers that harmonization in this area of great economical and social importance is a priority, taking into account the increasing use of such software-controlled instruments.

The Editors of the OIML Bulletin welcome the submission of technical papers and articles that address this important subject, which will doubtless become more complex in the near future, thus constituting a new challenge for OIML. ■

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APPLYING NEW TECHNOLOGIES IN LEGAL METROLOGY

Software verification for measuring instruments: a European approach

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Abstract

In legal metrology, protection against manipulation and quality assurance of software-controlled instruments are becoming increasingly important in view of the introduction of a modular conformity assessment procedure for industrial products (Council Directive 93/465/EEC) and the increasing use of such measuring instruments. However, neither commonly accepted approval procedures nor quality assurance systems for software used in measurement instruments exist.

It was the objective of this project to fill this gap. Under certain conditions a software analysis is necessary in an approval procedure as well as in quality assurance. Software analysis requires special know-how and is very costly. In the project technical aids have been developed which reduce the expenditure of examination and make the examination procedure more systematic. A program is described ("examination assistant") which is designed for registering and modelling a complex measuring system. This program decides whether a complicated software analysis is necessary according to the standard in legal metrology.

The software examination itself is performed by another program ("DFA tool", or Data Flow Analysis tool). It has been constructed on the basis of a data flow model and of structured software requirements. The examination assistant collects all data necessary for the data flow analysis from the knowledge gathered before. After the analysis of the data flow the examination assistant receives the results and interprets them.

The state of the art achieved at the end of the project results in a technical aid which is ready to be used in practice. Apart from some minor technical restrictions and handling difficulties, the essential features of the tools have been realized.

Appreciation

This project has been supported by the European Community under its "Measurement & Testing Program" (MAT), 1992-94", contract no. MAT1-CT92-0030. It contributes to the harmonization in Europe in an area of great economical and social importance.

Contents

1 Method of analyzing complex measuring systems

Considering the cost restrictions associated with approval tests, the concept of the procedures has to provide for the approval test of complex measuring systems to be automated and made as simple as possible for the officer in charge. In the following, an expert system is described that is able to assist the officer in charge in examining a complex measuring instrument. It is called an *examination assistant* ("X-Ass"). This program analyses a measuring system, determines whether an instrument or a component is subject to legal control, whether interfaces are protective, supports the checking of protection measures from unacceptable influences of the instrument, etc. One important item of the assistant is to facilitate software examination. The examination assistant is complemented by a software analysis tool described in section 2.3.

1.1 Description of the "X-Ass" expert system

1.1.1 Modelling realizations of instruments and relevant European Directives

The expert system described here is a program that keeps knowledge of legal metrology in the form of a database. This knowledge has to be entered into the database before the tool is used by one or more experts in this field (static knowledge). Besides this, information about the examined measuring system has to be entered; this is also kept in a database (dynamic knowledge). The officer in charge enters this knowledge during an examination session. For this purpose the program carries on a dialogue with the officer in charge via menu windows and a special graphic editor. The program then combines the knowledge from the static and the dynamic knowledge databases and obtains various examination results. In the following, the transformation of reality into the expert system software is described. First, some basic definitions used in legal metrology are given.

- **Measuring instrument.** This is the elementary term in legal metrology. An electronic measuring instrument (non-electronic instruments are not discussed here) has three basic functions: the conversion of various physical quantities into an electrical signal, the processing of this signal and the presentation of measurement values.
- **Peripheral device.** A peripheral device in the sense of this report is an equipment which:
  - is physically outside the instrument's own housing,
  - performs functions which are supplementary to the instrument's normal function, and
  - is not intended to correct or change the value of the measuring result.
- **Measuring system.** A complete set of measuring instruments and peripheral devices assembled to carry out a specific measurement task. A fuelling point and bill printer (and possibly additional devices) form the measuring system of a petrol station, for example.

On the basis of these terms two different models are constructed:

- *model of a measuring system in the relevant Directives (for the static knowledge) and*
- *model of a technical solution of a measuring system (for the dynamic knowledge).*

In law, under the European Directives and in subsequent requirements, only the *functions* of measuring systems are fixed, whereas the technical solutions used to fulfill these requirements are up to the manufacturer of the instrument. This means that an instrument is viewed on two different levels and this is taken into account when the reality is to be reflected in the examination assistant. According to the definition, a measuring system consists of one or more measuring instruments and of zero or more peripheral devices. The structure of both is identical, they only differ in some minor features (see below). Under the Directives and subordinated requirements, descriptions of functions are found and classified as follows:

- **Necessary functions.** These comprise the three basic functions of a measuring instrument already mentioned (quantity conversion, processing, presentation) as well as additional functions depending on various constraints (for example printing).
- **Admissible functions.** These comprise the necessary functions and additional functions which are either called "admissible" in a Directive or which are not called "inadmissible" and which do not intrude on or influence the necessary functions.
- **Inadmissible functions.** In some Directives, functions are named which are not admissible in measuring instruments for legal purposes.
- **Functional unit.** This term reflects the fact that functions always have to be realized in a concrete unit. A measuring instrument cannot only exist as a program but requires hardware too. Measuring instruments and peripheral devices consist of one or more functional units which realize one or

more of the admissible functions. In general a certain function is not prescribed to be realized in a certain functional unit. But if a measuring instrument component is to be constituted (see below) it is necessary to subdivide measuring instruments and peripheral devices into smaller parts which can be examined and approved separately. (The functional unit corresponds to the term *"part"* in the second model, see below).

- **Measuring instrument components.** This term stands for one or more functional units which can be examined and approved but do not constitute a complete measuring instrument or peripheral device. They can be combined with other functional units in order to realize a complete instrument. The type approval does not need to be repeated for the component in this case.

The difference between a measuring instrument and peripheral device in the model is that the first contains at least all *necessary functions*, whereas the latter does not contain at least one of the necessary functions. But this is not the only criterion, as individual regulations are found in the Directives. Printers, indicating devices or instruments which calculate new measurement values from measurement values received from measuring instruments are typical peripheral devices.

The *second model* represents the image of a technical solution of a measuring system. Again, a measuring instrument and a peripheral device consist of the same elements and have the same structure. Both consist of one or more *separate units* which again consist of one or more *parts*. These elements are defined as follows:

- **Separate unit.** A unit of this kind has a case or is encapsulated and can be connected via interfaces with other units. It is securable against manipulation, but whether it really has to be secured is decided by the approval examination.

Some measuring instruments such as electricity meters or taximeters and peripheral devices such as printers generally consist of only one separate unit. Weighing instruments often have a separate indicator with its own case or a loadcell in its own case. Here the separate units have to be connected via an interface in order to constitute a measuring instrument.

- **Part.** A part is defined as a group of electronic elements, concentrated on a printed circuit board, for example. The function realized by this part can be either necessary, admissible or inadmissible according to the definitions above. One part can realize one or more of these functions.

The objective of defining parts within a separate unit is to separate and identify all elements of the instrument whose functions contribute to protection against unacceptable influences, elements containing software, containing an interface etc.

1.1.2 Control of the software examination

When a part which contains a microprocessor is detected by the examination assistant, it makes several decisions concerning the software examination. First the software class is determined (see section 2.2.3). Depending on the software class, either a source code examination, checking according to WELMEC guide 2.3[1], or no software examination at all is executed. The examination assistant can also determine the specific software requirements relevant in this case which are part of the static knowledge.

At this time the examination assistant "knows" details about the hardware, the interfaces etc. of the examined measuring system from the previous course of the session. Missing knowledge is supplemented by dialogues with the operator. Some software classes require examination of the separation of the software into parts subject to legal control and parts that are not. This is performed by the DFA tool described in the following section. The examination assistant generates the input data for this tool:

- The starting points of the data flow analysis must be determined. The starting points in general are addresses of hardware components which X-Ass has already registered. From this information X-Ass derives a suggestion for the starting points which the user must confirm or correct.
- If the manufacturer has separated the software into one part subject to and one part not subject to legal control, he should have stated all modules and data structures of the part subject to legal control. The user of X-Ass must input these, as after the external data flow analysis a comparison is made between this input and the software separation actually detected.

After the output of the list of starting points, the session with the X-Ass program is interrupted and the preparation of the data flow analysis is continued externally by the operator of the DFA tool.

The user resumes the session with the X-Ass program as soon as he has got the results from the DFA tool. It consists of several lists in readable format and contains all functions or procedures and all variables which form the data paths subject to legal control. Now X-Ass compares the formerly input list of procedures

[1]) The WELMEC Guide 2.3 [2] was issued at the beginning of 1995 and conforms with the structured software requirements defined in this project - see also OIML Bulletin Volume XXXVII no. 1 (January 1996) pp. 11–14.

stated by the manufacturer with that generated by the DFA tool. If they are identical, the software has passed the examination. If they are not, X-Ass outputs the list of procedures which have not been stated and additional information on why these procedures are subject to legal control and how the manufacturer can avoid them being subject to legal control.

2 Procedure for software verification in legal metrology

2.1 Description of the theoretical basis for the analysis of software

The method of analysis is based on that adopted for conventional measuring instruments. A measuring instrument in legal metrology always consists of a sensor, a part which processes the measured values and transforms them into a format which can be displayed, and an indicating device. In a conventional measuring instrument, the measured values are processed either mechanically, electro-mechanically, by analogue electronics or by digital electronics using fixed programs. Even if the processing of the measured values is done by a microprocessor, this part is still considered a "black-box", and its internal functions are not analysed. For today's software-controlled measuring systems, black-box testing is unsuitable if the protection from unacceptable influences, conformity of an instrument with the approved pattern or identification of software are concerned.

2.1.1 Life-cycle of measurement values

Measurement values enter the instrument via an input and leave it via an output (or to a built-in display). The connection between the physical exterior interfaces of the instrument is represented inside by the *data path*. The hardware input of the instrument represents the software source and the output or display the software *drain*. Starting at the source, the measurement values reach the drain via the data path, by being transported by *programs*. Data transport takes place incrementally in phases. In each phase, the values are represented in *variables* (Fig. 1). While passing from one phase to the next, the values can be modified and stored in another variable, initiated by a program module. A data path covers all variables used during the entire data life-cycle and the program modules involved.

After having gone through all phases, the raw measurement value (as it entered the input) has been transformed into the required output format, for example a real number with correct unit, and it can now be passed on to the output or display (drain). Generally, the raw values are transformed by more or

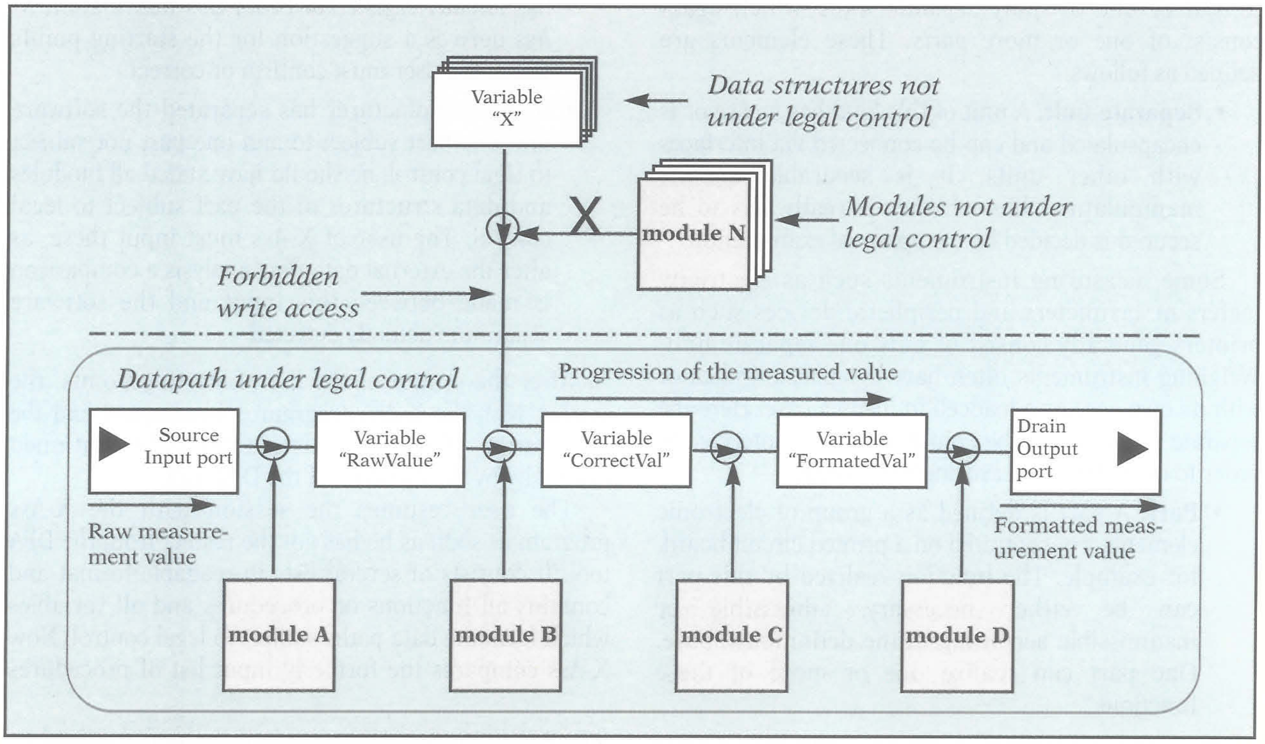

Fig. 1 Immunity of the data path under legal control

less complicated arithmetic or logic algorithms - i.e. the measurement value is related to other data. The graph of the data path therefore has sidepaths which come from other inputs or variables containing constant figures, and it can also have sidepaths which lead to different drains.

2.1.2 Software separation and immunity of the data path under legal control

As mentioned above, modern instruments are characterized by manifold functions. Often only some of them are under legal control. The instrument manufacturer is interested in profiting from the flexibility of software technology in order to realize the wishes of the customer. A change in the instrument functions usually requires another type approval which involves additional costs and time delays.

If it is guaranteed that only those functions that are not under legal control are changed, the type approval need not be repeated. This can be achieved if all functions under legal control are realized by an approved set of data paths (main paths and side paths, called *"data paths under legal control"*), and all other functions are realized by another set of data paths. The manufacturer may freely construct data paths **not** under legal control as long as those that **are** under legal control are neither changed nor influenced. But this is only possible if some aspects that effect a *separation of the software* into parts under legal control and parts not under legal control are observed. Fig. 1 illustrates what is meant by this: below the dotted line a data path under legal control is shown, whereas there are other data structures and program modules for purposes not under legal control above the line. The programmer must observe the following restrictions which are to guarantee the *"immunity of the data path under legal control"*:

a) Transport and processing of data inside the data path under legal control must be performed only by program modules belonging to the data path under legal control.

b) No data must be transported by programs outside the data path under legal control from variables not under legal control to those belonging to the data path under legal control (*"Forbidden write access"* in Fig. 1).

c) No data must be transported by programs outside the data path under legal control from variables not under legal control to the *drain* of a data path under legal control.

d) The start of the processing of measurement values must not be prevented or delayed inadmissibly by program modules not belonging to the data path under legal control.

The manufacturer has to observe these restrictions for that part of the software not under legal control and leave that part which is under legal control unchanged. The software tool developed in this project examines the compliance of the software of a measuring instrument with the above-mentioned restrictions.

2.1.3 Protection against unacceptable influences

Unlike to the manufacturer, who is obliged to manufacture the measuring instrument in compliance with the approved type and who risks the approval being revoked if he fails to do so, the user of the instrument must be *prevented by technical means* from circumventing the software separation described above. As regards personal computers, this requirement can generally be met only by the use of additional hardware which can be secured by protecting against removal or changes.

So far, reference has been made only to the life-cycle of measurement values which are within a part of a measuring system under the control of a program belonging to the data path under legal control. If measurement values are transmitted between parts of the system, the connection must in general be physically protected. Alternatively, the measurement values can be secured by software means. The measurement value life-cycle model can be expanded into a complete measuring system. In all phases of the life-cycle when measurement values are not under the control of a program which is part of a data path under legal control - i.e. when the measurement values are transmitted, stored or processed by any unknown program - they must be protected by encryption or electronic signature. Software protection of the data object is equivalent to conventional mechanical sealing, but makes the realization of "open systems" possible.

In the following chapter, requirements are formulated which refer to the various phases in the life-cycle of the measurement values.

2.2 Requirements of software-controlled instruments in legal metrology

The main idea of the following section is the systematic structuring of the requirements in order to achieve lucidity and completeness. In software engineering a good development technique is the top-down approach. Applied to the problem under consideration, in the first step (subsection 2.2.1) structured general requirements are derived from the relevant regulations. Subsequently, several conditions which have an influence on the different points of view of the approval departments (and agencies) are generalized and used for a classification of software (subsection 2.2.3). For each software class a set of specific detailed requirements exists.

2.2.1 General structured software requirements

The legal metrology software requirements comprise three aspects:

- *protection against manipulation of software-controlled measuring instruments,*
- *changing of pattern-approved software by the manufacturer,*
- *identification of pattern-approved software at verification.*

Permissible errors and the correctness of measurements were deliberately excluded, as also in future, the physical properties of the measuring instruments are to be examined by means of conventional, typical testing methods.

As mentioned above, the software requirements are hierarchically structured. The highest level is characterized by a few general basic requirements which should apply to all categories of measuring instruments and scopes of application. They are based on legal provisions, EU Directives [3], European Standards 45501 [4] and on the state of discussions in WELMEC working groups.

The structure of the general software requirements is shown in Fig. 2. Considering the life-cycle of measurement values or relevant data, it is obvious that this requirement must be fulfilled during the whole life-cycle of the relevant data. According to subsection 2.1.3 there are two phases: the phase in which relevant data are under the control of a program subject to legal regulations (i.e. when they are on a data path under legal control), and the open phase when the relevant data are not under the control of such a program.

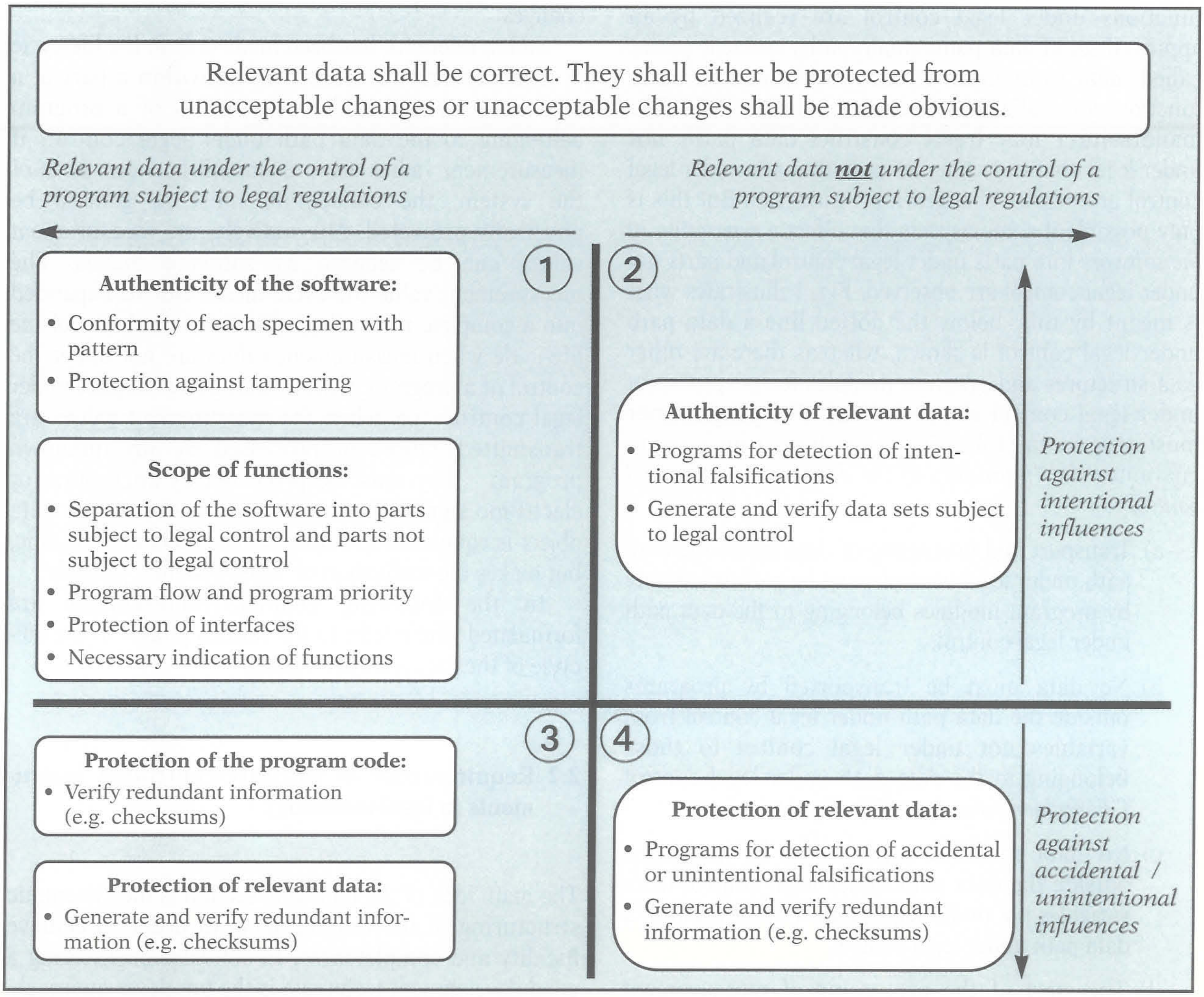

Fig. 2 Structured general software requirements

This leads to different interpretations of the basic general requirement at the top of Fig. 2 for both phases and two groups of sub-requirements. These groups must in turn be subdivided, as two kinds of influences must be taken into account which can cause "unacceptable changes": in legal metrology, a distinction is made between the *intentional* and *unintentional* or *accidental influence*. As shown in Fig. 2, the structured requirements can be subdivided into 4 quadrants which are related to the properties of the software. The following assumptions have been made:

- It is assumed that *data under the control of a program* cannot be intentionally influenced directly, but *only indirectly* when other programs are used or the controlling program is influenced. As regards intentional influences, only the *programs*, not the data themselves must be considered (requirements 1 and 2, quadrant 1 in Fig. 2).
- However, when data are under the control of a program, they can nevertheless be **accidentally** influenced directly. General requirements 3 and 4 take this into account (quadrant 3 in Fig. 2).
- When relevant data are **not** under the control of a program subject to legal regulations, requirements 5 and 6 must be fulfilled (quadrants 2 and 4 in Fig. 2).

2.2.2 Specific requirements

Requirements 1 to 6 are applicable to all technical realizations and do not take into consideration any properties of the software, nor the operating conditions of the measuring instrument. As there is great variety in the design of software used in software-controlled instruments and many factors influence its functions, more detailed requirements are needed for practical application. On the other hand a complete set of detailed requirements would be too complex. Therefore only those requirements that are relevant to the instrument concerned are extracted from the complete pool of requirements.

The selection of the set of specific requirements is based on a classification of the instrument or the software using several classification criteria. For example, the *"area of legal application"* or the *"variability of the software"* are criteria for classification. A software class is described by a characteristic of each criterion.

For each software class a specific set of requirements exists. An instrument used in the *"direct sales to the public"* area of legal application and the software variability *"software exchangeable by the manufacturer"* must fulfill another set of requirements which differ from those for an instrument for traffic control (area of legal application: *"official dealings"*) with sealed memory (software variability *"software not changeable after legal verification"*). How the software classification is carried out and which criteria must be taken into consideration are described in the following section.

2.2.3 Classification of the software

In selecting the set of requirements relevant to a certain instrument, a distinction is made between pure software criteria and legal criteria. The following software criteria are taken into account:

- **Software variability**. In order to do justice to practical requests, software manufacturers and in some cases even the user of the instrument may alter parts of the measuring instrument software under certain conditions. To what degree this is possible is described by the *"variability"* criterion. Programs and data which realize functions under legal control or which are used for such functions are called *programs or data subject to legal control*. Other programs can be combined with the controlled programs. Functions of the measuring instrument can also be changed by data which activate or deactivate program variants.
- **Software environment**. The software of the instrument can be produced completely by the manufacturer, or a standard operating system can be used. Programs subject to legal control may be installed alone or combined with programs not subject to legal control. These variants are taken into consideration with the "software environment" criterion.
- **Legal operating mode**. Measuring instruments have different operating modes which the user can control or which he can observe. Instruments subject to legal control may have operating modes not subject to legal control. The indicating device in particular may display values subject to legal control as well as those that are not.
- **Area of legal application**. This criterion describes the legal context (e.g. direct sales to the public, official application).
- **Kind of instrument**. The criteria mentioned above are valid for all kinds of measuring instruments in legal metrology. However there are

further aspects relevant to software classification in type approval because instruments must always fulfill certain physical requirements. It is the objective here to give software requirements which harmonize with requirements originally given on the kind of measuring instrument, and which also harmonize with the individual requirements of the approval department (or agency). Some of these requirements may not coincide with those of another department. The type of instrument or the department responsible is therefore judged as a criterion for software classification. Another four sub-criteria are defined which respectively describe the requirements specific to the instrument or department. These sub-criteria are only used for classification if they are relevant to the original physical requirements of the department. The individual requirements may depend on whether:

- the unit examined is a measuring instrument or a peripheral device;
- the measurement or the evaluation of measurement values is repeatable;
- the instrument is used when both parties or only one party concerned with the measurement result are present;
- there is a probability of fraudulent actions;
- the measurement value has to be interpreted or confirmed by a specialist;
- the properties of the measuring instrument are not to be examined or tested in type approval but in a subsequent verification.

2.3 Software analysis

In the previous sections it has been made clear that the problem of the treatment of software in the framework of a type approval procedure in legal metrology is both technical and economic. The combination of the X-Ass examination assistant and the software analysis tool described in the following is intended to reduce this problem. The examination assistant controls the examination procedure, invokes the software tool only if it is necessary, generates the input data for the tool, processes its results and integrates them into the examination report.

Until now, no complete testing procedure such as that in an industrial production process has been necessary for software examination in legal metrology. Only those aspects of the software are examined which cannot be tested by other (conventional) means. The subjects of the examination described in this project are:

- to examine whether the structure of the software allows the manufacturer to change or modify parts of the software after type approval without violating the conformity of the measuring instrument with the approved pattern,
- to examine whether the structure of the software guarantees sufficient protection from unacceptable influences of the measuring instrument.

However, the analysis described in the following does not examine the correctness of the measuring algorithm or maximum permissible errors.

2.3.1 Description of the analysis tool

The DFA software analysis tool checks the immunity of the *data path subject to legal control* (see section 2.1) on the basis of a static source code analysis. This tool covers most of the steps a compiler performs; indeed it is only the last step which differs: for data flow analysis code generation is omitted and a special analysis of the output of the parser and of the semantical analyser starts.

Some tools are commercially available for static and dynamic analysis of software. None of them alone was suitable for a complete examination of the immunity of a data path. As the best solution, a combination of two commercially available tools combined with a program to be produced in the project was chosen:

- the source code analyser (SCA) from DEC (Digital Equipment Corp.) for the analysis of the data flow,
- LOGISCOPE from Verilog for the analysis of the controlflow and
- the DFA program for searching for chosen data paths, generating images of data paths and for linking to the X-Ass examination assistant.

SCA and especially LOGISCOPE are versatile tools. The above-mentioned scanner, parser and semantical analyser are elementary components of these. The DFA program realizes interfaces for the input and the output of the commercial tools and performs a preprocessing of the source code and a postprocessing of the tool results.

The basis of the analysis is the model of the data path subject to legal control (described in section 2.1.). The DFA tool is able to determine data paths, i.e. it extracts and collects all variables, constants and functions (modules) which form the data path. If a drain is selected (a hardware address is input), the tool finds the elements of the data path in reverse order from the drain to all sources.

The DFA tool cannot distinguish whether or not the selected path is subject to legal control, whether the path determined exactly covers the path subject to legal control, or whether more parts of the software are involved. This evaluation is performed by the X-Ass examination assistant in a postprocessing procedure.

The list of drains belonging to data paths subject to legal control is generated by X-Ass. As it in any case collects some information concerning the hardware of the instrument, the number of questions posed to the user of X-Ass can be reduced to a minimum. This list is output in ASCII format (readable text). During an analysis session the operator of the DFA tool must work off all drains of the list one by one. The operator must know the "C" programming language and be instructed about the computer platform (DEC hardware, VMS operating system, VAX C compiler).

The main task of the operator is preprocessing the source code and converting it to a standard form (the VAX dialect of "C"). Though the language "C" (which can be analysed alone by the tool in question) was constructed as a portable language, there are many peculiarities of the various compilers that must be eliminated before analysis; this is manual work.

The DFA tool generates a graphic output and lists in ASCII format. They contain all variables and functions which constitute the data path belonging to a given drain. The X-Ass examination assistant reads these lists and checks the correspondence with the lists declared by the manufacturer. The result of this partial examination is integrated into the overall report by the X-Ass program.

2.3.2 Limitations of the analysis

With the state of development reached at the end of the project, rather complex software problems can be handled with an expenditure of time and resources not far from an acceptable level for a type approval in legal metrology. However, for real practical application further improvement is appropriate to redress the following limitations:

- Preprocessing of the source code is currently performed manually and requires a skilled operator. Preprocessing could be automated to a certain degree by technical enhancement of the tool.
- Some constructions cannot be analyzed by the tool but only manually. This problem can be redressed by enhancement of the control flow analysis and by programming rules which the programmer of the program to be examined has to observe.

3 Conclusions

The main task of the project was the development of technical aids for carrying out the analysis and examination of complex measuring instruments in legal metrology. An analytical system consisting of two stages has been developed: first an expert system backs up the officer in charge in the approval procedure in the course of which it is determined whether a software examination is necessary or not and which specific requirements are valid for this instrument. If a software examination is necessary, this can be performed with the aid of the second tool developed in the framework of the project.

Though some technical deficiencies of the tools could not be eliminated within the framework of this project nothing bars their practical use. It seems efficient to gain some experience in practical approval procedures before continuing the development of the tools. In spite of the limitations perceived the tools will be a useful aid in approval examination and in quality assurance of complex measuring instruments.

The full final report [5] contains a proposal for the integration of the X-Ass and DFA tools into the quality assurance system of the software production process of measuring instruments. Thus conformity with the software requirements in legal metrology can be guaranteed already at an early stage in the software production process. ■

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A NEW TOOL FOR METROLOGICAL LABORATORIES

Using networks to study and control the maintenance and surveillance of standards

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Abstract

This paper presents the concept of using network topology to study and control the metrological maintenance and surveillance of standards. Multistandard staircase and data-based representation networks are proposed for the group comparison of standards. A comparison of the networks is given, along with an uncertainty analysis.
Keywords: Electrical Metrology, Standards Surveillance, Metrology Network.

1 Introduction

Those metrological laboratories ranked next to national level laboratories and a number of national level standardizing laboratories maintain their standards for reference purposes. Today's reference standards are of such quality and stability as to maintain their values over long periods of time: recent advances in technological fields have provided standards with results of one part per million (ppm) or better. These are now used as reference standards for calibrating working standards in laboratories requiring measurements of extremely high precision. When maintaining reference and working standards at secondary metrological laboratories, techniques which provide and maintain traceability to the world's highest level laboratories and which result in a decrease in the frequency of external calibration traceability checking must be employed.

During normal calibrating operations, a value is assigned to an unknown standard by comparing it directly against a certified reference standard. Thus in a group of N standards, the calibrated value of each standard will be the average of the N – 1 values. In general, metrological maintenance/surveillance of standards involves the group comparison of standards (i.e. each standard is compared to every other standard) and the results are arranged in matrix form. Table 1 shows the complete comparison pattern for a group of five standards. The measurement data for each row is found by comparing the unknown row standard against the known reference column standard, and the calibrated values of the standards are obtained based on row-column matrix operations [1 – 4]. For large groups of standards a complete comparison pattern may result in more work, therefore partial comparison patterns are also proposed. Table 2 shows a partial comparison pattern for a group of six standards. The complete and partial comparison patterns for a group of N standards will contain $N(N - 1)$ and $N^2/2$ data points respectively.

Networks are proposed for complete and partial comparison of standards, useful for controlling the selection of calibration methods. Some ideas about networks are given in reference [5].

2 Maintenance / surveillance: multistandard staircase network

Consider a group of N standards. In this surveillance/maintenance system, the calibrated value of an (unknown) standard is obtained by comparing it against the remaining standards, taking the latter as the reference standards. Thus each standard in the group will have N – 1 calibrated values which are averaged to reach the final calibrated value. Fig. 1 (a) shows a staircase topology of such a maintenance/surveillance system for a group of five standards (N = 5). There are five channels of standards and five nodes. Each node represents the average calibrated value of a standard, which is obtained by comparing its standard against the remaining four standards in the group. Each node is compared to four standards, i.e. the standard set of each node contains four reference standards. A directed path from standard j to node i indicates that the standard which represents node i is measured using standard j as the reference. Fig. 1 (b) gives an abstract representation of the network: the solid circle j and node i symbolize the fact that the node i standard was compared to the reference standard j. Node i is deemed to be connected to standard j. The value of each node implies that its corresponding standard during the normal calibration process was connected only to the *unknown* port of the measurement system. Reverse mode operation (i.e. the node's standard is connected to the reference port) is equally possible but will not be considered here.

Unknown	Reference A	B	C	D	E
A	0	ρ_{BA}	ρ_{CA}	ρ_{DA}	ρ_{EA}
B	ρ_{AB}	0	ρ_{CB}	ρ_{DB}	ρ_{EB}
C	ρ_{AC}	ρ_{BC}	0	ρ_{DC}	ρ_{EC}
D	ρ_{AD}	ρ_{BD}	ρ_{CD}	0	ρ_{ED}
E	ρ_{AE}	ρ_{BE}	ρ_{CE}	ρ_{DE}	0

Table 1 Complete comparison pattern for a group of five standards.

Unknown	Reference A	B	C	D	E	F
A	0	ρ_{BA}		ρ_{DA}		ρ_{FA}
B	ρ_{AB}	0	ρ_{CB}		ρ_{EB}	
C		ρ_{BC}	0	ρ_{DC}		ρ_{FC}
D	ρ_{AD}		ρ_{CD}	0	ρ_{ED}	
E		ρ_{BE}		ρ_{DE}	0	ρ_{FE}
F	ρ_{AF}		ρ_{CF}		ρ_{EF}	0

Table 2 Partial comparison pattern for a group of six standards.

One of the factors which affects the performance of the multistandard network is the bandwidth available to groups that share at least one standard. For example in Fig. 1 (a), nodes 2, 3, 4 and 5 share only standard 1, whereas nodes 1, 2 and 3 share both standards 4 and 5. It is clearly advantageous for the group members to share more standards as this implies more potential parallelism in comparison between group members. In staircase type maintenance/surveillance topological networks, a multipath operation will require comparison against more than one reference standard in order to reach the desired set of paths. A full staircase topology of maintenance/surveillance, as

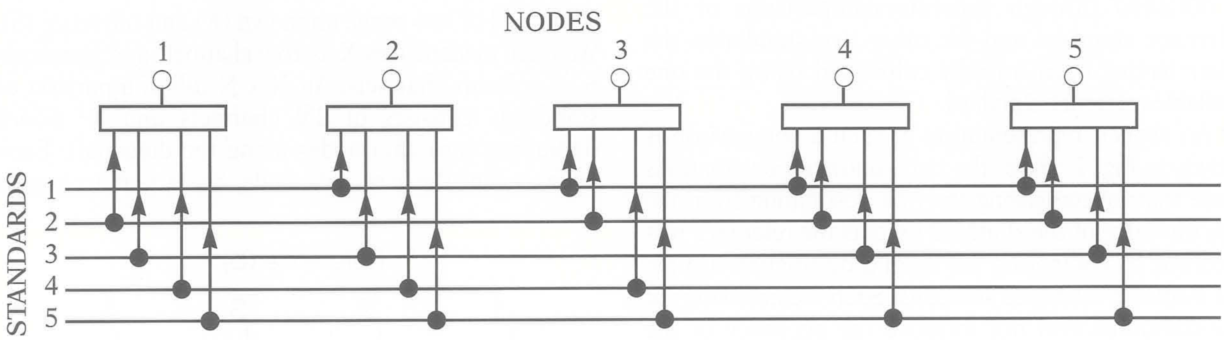


Fig. 1 (a) Explicit representation of a multistandard staircase network

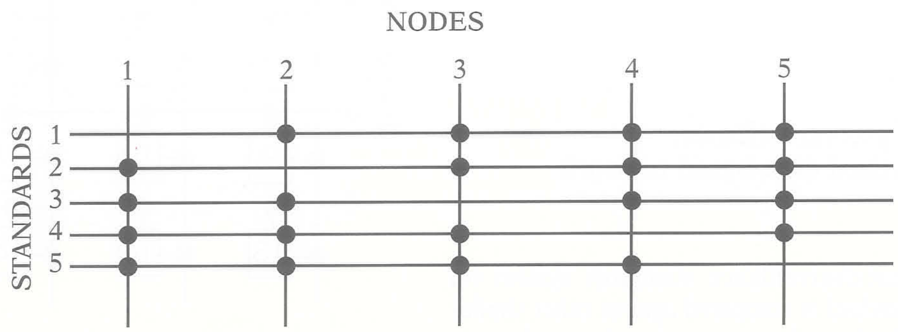


Fig. 1 (b) Abstract representation of a multistandard staircase network

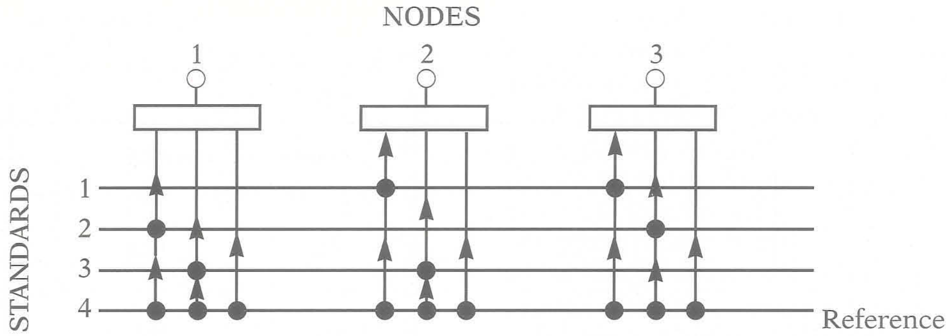


Fig. 2 Explicit representation

shown in Fig. 1, is one in which each node i standard is compared to N – 1 standards. The total number of paths in a group of N standards is N(N – 1).

A reference standard case

In most secondary metrological laboratories, calibration is usually carried out using one reference standard (traceable to a national level laboratory) to calibrate other standards which are then intercompared. Consider a group of four standards containing one reference standard. In this group the calibrated value of a standard, other than the reference standard, will be an average of three values. Each value is obtained through separate comparisons of the reference standard and the other two standards, the latter having been initially calibrated using the one available reference standard.

An explicit representation of such a comparison is shown in Fig. 2. Here, the two continued destinations mean that by comparing the first destination from the top, the value of the standard used as the reference was obtained by comparing the second destination against the available reference standard. Such a comparison of the standards will not improve the accuracy of the results, as paths with two arrows lead to large uncertainties. It is therefore recommended to establish one standard node set with respect to the one available reference standard, rather than intercomparing them.

3 Maintenance/surveillance: multistandard data-based network

The maintenance/surveillance standards system (in which each standard is compared against other similar types of standards and measurement data written in matrix form) is presented as a multistandard data-based network. A multistandard network consists of parallel multiple access standards multiplexed on a single physical medium, i.e. each standard assumes both states (unknown and reference) while data is recorded. Consider a group of four standards. The calibrated value of each standard in the group is obtained using the methods involving row-column matrix operations. The complete comparison pattern for a group of four standards will contain twelve data points.

Figure 3 (b) depicts an eight channel network whose logical topology is actually a 4 × 4 matrix as shown in Fig. 3 (a). Nodes 1-6-11-16 which form the diagonal are zero data nodes (no measurement), as in practice a standard is never compared to itself. The standards in a two dimensional maintenance/surveillance model are composed of two ports, unknown (X) and reference (S). We refer to standards X as row channels and standards S as column channels. An N × N full comparison of standards consists of 2N channels and N^2 nodes (including zero data nodes along the diagonal). Each node, except the zero data node, has a port to exactly

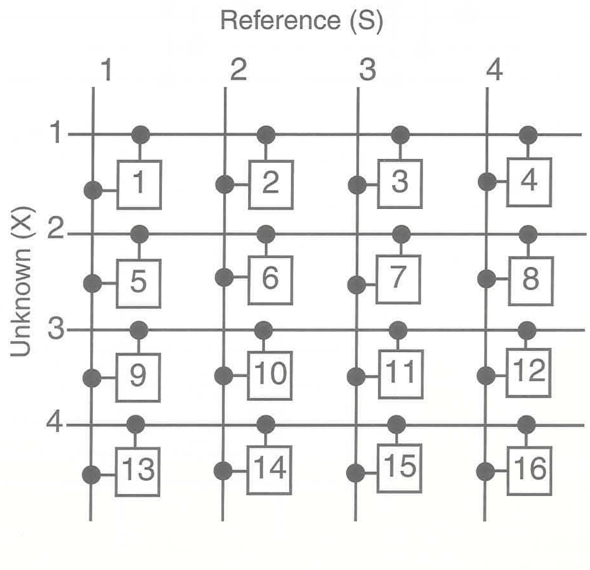
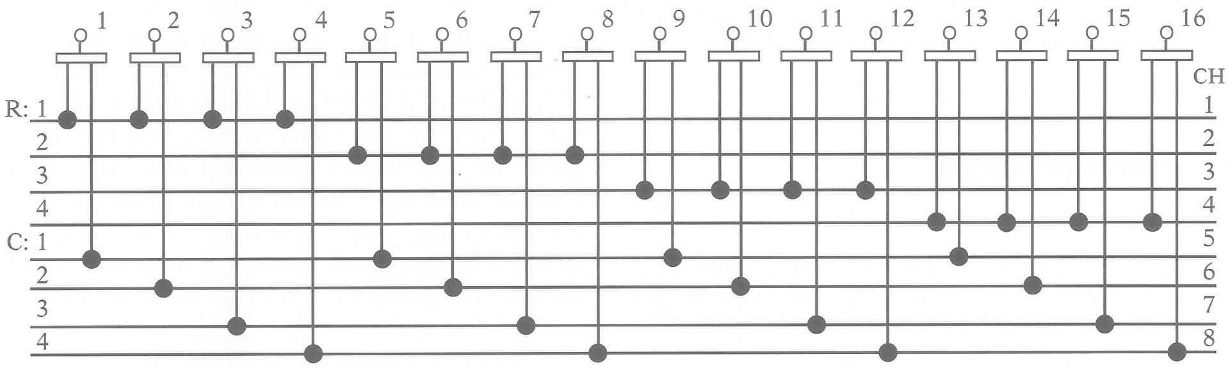


Fig. 3 (a) Data representation



R: Row, C: Column, CH: Channels.

Fig. 3 (b) Multistandard representation (8 channels)

one row standard and one column standard (that is, one reference/unknown pair) and thus has degree two. Figure 3 (a) is an example of a 4 × 4 full comparison pattern of standards. The unknown and reference standards are respectively depicted as horizontal and vertical lines. A partial comparison of the standards contains its own subset of nodes which, together with their channels, composes a full comparison of the standards.

The maximum such subset of nodes is termed the core of the network. An example of a two-dimensional partial comparison of four standards is shown in Fig. 4. In a partial comparison there are $N^2/2$ measurements (N is even), and $(N^2/2) + N$ nodes which also includes the zero data nodes along the diagonal. In Fig. 4, the core of the network consists of the four upper left nodes. If the zero data nodes are not considered, then the core of the network will be the two upper left nodes, i.e. nodes 2 and 4.

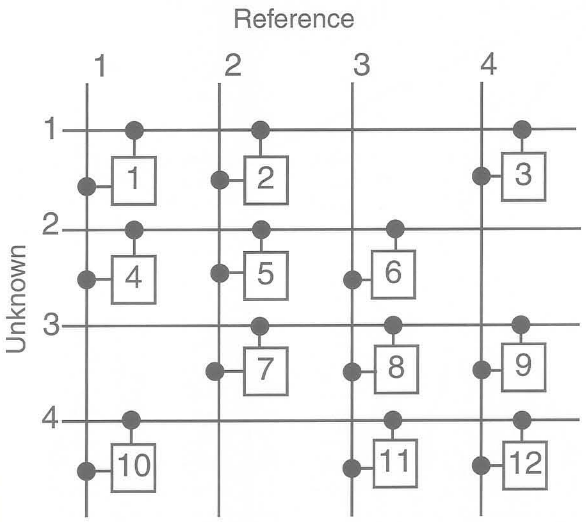


Fig. 4 Partial data representation

In a multistandard data-based network, a defective column channel means that all data nodes based on that particular column channel standard are wrong. Therefore, the reference standard that designates the defective vertical channel should be replaced. Incorrect data resulting on the row channel implies (i) that all reference standards are defective, which is not acceptable for a group of precision standards requiring a high level of stability, and (ii) that the unknown standard corresponding to the defective row is unstable, which is more probable. In this case the unknown standard designating the defective row must be replaced or discarded. This action will also eliminate the corresponding vertical channel in which the same standard is used as the reference.

4 Comparison of maintenance/surveillance networks

(i) In multistandard data-based network topology, the media are based on multiple comparison (or access) as opposed to standard-to-standard; this corresponds to the number of reference and/or unknown channels required in the network. In a standard-to-standard logical topology, the number of channels is the same as the number of nodes. But in a complete data square the number of channels is proportional to $2X^{1/2}$, where X is the number of data nodes (including zero data nodes).

(ii) Multistandard data-based networks are bi-directional in the sense that if standard A can be compared directly as unknown against standard B, then through reverse mode operation standard B will be compared as unknown against standard A. Bi-directional comparison improves the accuracy and reliability of the results.

(iii) In multistandard data-based networks, all data nodes (except the diagonal nodes) involve two standards, and only a small number of standards is required to obtain a large number of sets of data.

5 Uncertainty analysis

Statements about uncertainty of methods depend on the uncertainties of the various measurements as well as on the design of the experiment. Guidelines for evaluating and expressing uncertainty in measurements are well defined in references [6, 7]. A graphical method is proposed here for determining the uncertainty when the standards are maintained as (i) a staircase network and (ii) a data-based network (for illustration purposes the matrix method defined in [2] is considered here).

(i) Consider node 1 in Fig. 1 (a), which is connected to four standards in a group of five standards as shown in Fig. 5. Let the standard uncertainty of the accepted value of each standard i be u_i, i = 1 to 5, which is given by a source outside the subject calibration system. In Fig. 5, there are four paths (BA, CA, DA, EA), each of which has an associated element of uncertainty. Let the standard uncertainty associated with paths BA, CA, DA and EA be u_{BA}, u_{CA}, u_{DA} and u_{EA}, respectively. The standard uncertainty of the path is considered equal to the positive square-root of the sum of the squares of the standard uncertainties, due to repeated measurements, the measuring system, etc. If the standards are similar and one measurement system is used, then the standard uncertainty associated with each path will be of approximately the same magnitude.

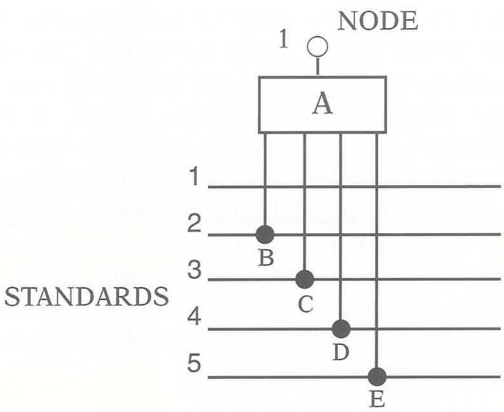


Fig. 5 A single node, five-standards staircase network

Now the combined standard uncertainty of node 1 due to its comparison with standard 2 via the path BA is

$$\left(u_2^2 + u_{BA}^2\right)^{1/2}$$

Hence an estimate of the combined standard uncertainty associated with the calibrated value of standard 1 which is compared to the remaining four standards of the group will be the mean of the uncertainties associated with all the paths:

$$[(u_2^2 + u_{BA}^2)^{1/2} + (u_3^2 + u_{CA}^2)^{1/2} + (u_4^2 + u_{DA}^2)^{1/2} + (u_5^2 + u_{EA}^2)^{1/2}]/4$$

Similarly the combined standard uncertainty associated with the other nodes in Fig. 1 (a) can be determined.

(ii) In a multistandard data-based network, for a group of five similar standards, there will be 20 data nodes (excluding the zero data diagonal nodes). For

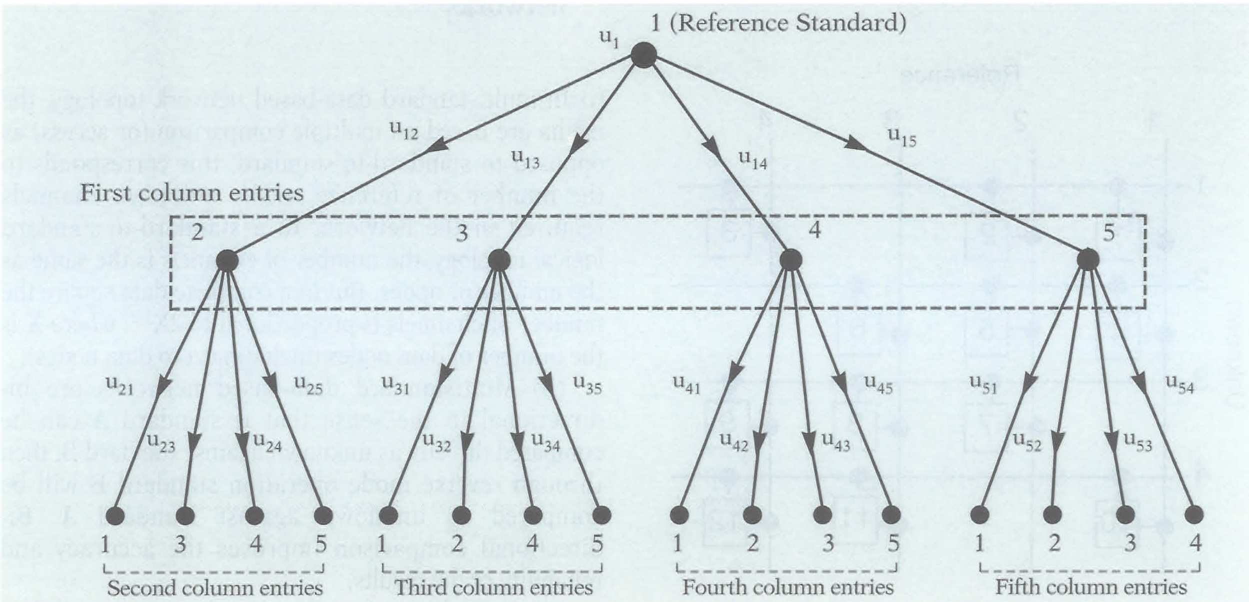


Fig. 6 A directed path for a group of five standards with standard 1 as the reference

Unknown	Reference 1	2	3	4	5
1		$(u_1^2 + u_{12}^2 + u_{21}^2)^{1/2}$	$(u_1^2 + u_{13}^2 + u_{31}^2)^{1/2}$	$(u_1^2 + u_{14}^2 + u_{41}^2)^{1/2}$	$(u_1^2 + u_{15}^2 + u_{51}^2)^{1/2}$
2	$(u_1^2 + u_{12}^2)^{1/2}$		$(u_1^2 + u_{13}^2 + u_{32}^2)^{1/2}$	$(u_1^2 + u_{14}^2 + u_{42}^2)^{1/2}$	$(u_1^2 + u_{15}^2 + u_{52}^2)^{1/2}$
3	$(u_1^2 + u_{13}^2)^{1/2}$	$(u_1^2 + u_{12}^2 + u_{23}^2)^{1/2}$		$(u_1^2 + u_{14}^2 + u_{43}^2)^{1/2}$	$(u_1^2 + u_{15}^2 + u_{53}^2)^{1/2}$
4	$(u_1^2 + u_{14}^2)^{1/2}$	$(u_1^2 + u_{12}^2 + u_{24}^2)^{1/2}$	$(u_1^2 + u_{13}^2 + u_{34}^2)^{1/2}$		$(u_1^2 + u_{15}^2 + u_{54}^2)^{1/2}$
5	$(u_1^2 + u_{15}^2)^{1/2}$	$(u_1^2 + u_{12}^2 + u_{25}^2)^{1/2}$	$(u_1^2 + u_{13}^2 + u_{35}^2)^{1/2}$	$(u_1^2 + u_{14}^2 + u_{45}^2)^{1/2}$	

Table 3 Combined standard uncertainty associated with the values when standard 1 is used as the reference standard

illustration purposes, the combined standard uncertainty associated with the calibrated values (obtained based on the matrix method given in reference [2]) is calculated. Using the matrix method, calibrated values are obtained by treating each standard as a reference standard at any one time. Consider standard 1 as the reference standard, used to compute the values of the other standards. Thus the first column of the 5 × 5 order matrix can be completed using the normal method of operation, in which one data node is used to compute each value.

The values of the first column may now be used as reference values representing the respective standards, in order to complete the entries of the other columns in the same matrix. A directed path for this group when standard 1 is used as the reference standard is shown in Fig. 6.

The combined standard uncertainty associated with each computed value when standard 1 is used as the reference standard is given in Table 3.

In Table 3 the mean of each row is calculated as u_{ri}, i = 1, ..., 5 and the mean of each column as u_{cj}, j = 1, ..., 5. Thus the combined standard uncertainty associated with the deviations from the mean values of the standards is:

$$u_{Di'} = (u_{ri}^2 + u_{cj}^2)^{1/2}; \quad i, j = 1, ..., 5.$$

Since standard 1 is considered as the reference standard, it is used to obtain the values of the other standards, thereafter $u_1 - u_{d1} = u_{M1}$ (say) may be calculated. Therefore, the combined standard uncertainty associated with the calibrated values of standards 2, 3, 4 and 5 is respectively:

$$u_2 = u_{M1} + u_{D2},\ u_3 = u_{M1} + u_{D3},\ u_4 = u_{M1} + u_{D4}, \text{ and } u_5 = u_{M1} + u_{D5}.$$

Since standards are similar, if one measuring system is used then the uncertainty values obtained with respect to one reference standard will be accurate enough as they will remain the same for other reference standards.

Example: Consider a group of four similar standards (S1, S2, S3, S4) which are compared using one measurement system. Let the standard uncertainty associated with the reference value of each standard and path be ± 0.08 ppm and ± 0.17 ppm respectively.

(i) For a staircase network, the combined standard uncertainty associated with the calibrated value will be ± 0.19 ppm.

(ii) For a data-based network, the combined standard uncertainty associated with each computed value when standard S1 is used as the reference is as in Table 4.

Unknown	Reference S1	S2	S3	S4	Row mean
S1		0.253	0.253	0.253	0.253
S2	0.188		0.253	0.253	0.231
S3	0.188	0.253		0.253	0.231
S4	0.188	0.253	0.253		0.231
Column mean	0.188	0.253	0.253	0.253	

Table 4 Combined standard uncertainty

Now the combined standard uncertainties (in ppm) associated with the deviations from the mean values of the standards are

$$u_{D1} = 0.315,\ u_{D2} = 0.343 = u_{D3} = u_{D4}.$$

Since standard S1 is considered as the reference standard, therefore $u_{M1} = -0.235$ ppm. Hence, the combined standard uncertainty associated with the calibrated value of each standard (S2, S3, S4) is ± 0.11 ppm.

6 Conclusions

This paper presents a new tool which may be used to study and control group maintenance/surveillance of standards, based on network topology. In group maintenance/surveillance of standards, it is recommended to adopt such methods that constitute a multistandard data-based network. When only a single standard with national level laboratory certification is available for calibration purposes, it is not advised to carry out group surveillance/maintenance of standards based on staircase representation. The uncertainty analysis provides one means of calculating the combined standard uncertainty in the measurement results of group calibrations.

Acknowledgments

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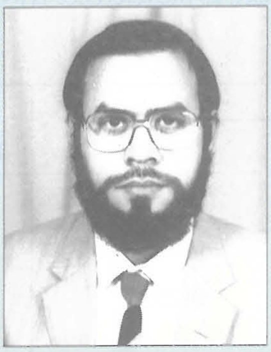
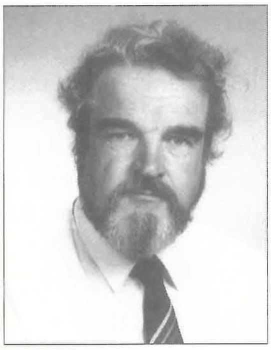


Left: Rahat Husain, Metrologist
Right: Dr G.M.S. de Silva, Manager of the Measurement Standards Laboratory, Division V, Research Institute, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia.



AUTOMATIC CONTROL SYSTEMS

Practical problems of using non automatic weighing instruments in automatic process lines

OIML Seminar WEIGHING TOWARDS THE YEAR 2000

13–15 September 1995 Maison de la Mécanique, Paris

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Abstract

Over the past few years the development of automatic control systems has been very effective. The control of machines and different process lines has been automated in a way which was unimaginable 15 or 20 years ago. Determining between non automatic weighing instruments (NAWI) and automatic weighing instruments (AWI) is generally done just before automation. In the case of certain processes where NAWI have been automated, one wonders whether the automation applies to the NAWI or to the operator.

1 Elements of legal metrology used to define NAWI and AWI

a) Non automatic weighing instruments (NAWI)

The definition in R 76 states that a NAWI is "an instrument that requires the intervention of an operator during the weighing process ...". This is in fact the main definition, but additional points develop the concept further:

- the instrument allows direct observation of the weighing result
- presence of an indication stabilizing device
- presence of a zero-setting device
- discrimination threshold
- after a change in load, the previous indication shall not persist for longer than 1 second.

b) Automatic weighing instruments (AWI)

The definition in the various OIML Recommendations states that an AWI is "an instrument which weighs without operator intervention and follows a predetermined program of automatic processes, characteristic of the instrument".

For all AWI's, typical characteristics also exist:

- the weighing result is usable within a given period ("dynamic equilibrium")
- an AWI does not require the display to continuously indicate the weighing result
- an AWI should have an automatic function for:
  - zero and/or tare
  - recording of the weighing result apart from the preset value
  - transporting the weighed object onto and off the load receptor
- continuous weighing without any operator intervention

c) The weighing instrument could fall into either category

Sometimes an AWI weighing instrument could equally be classified as a NAWI instrument, the only difference being that no operator is present. Is it necessary to classify a NAWI as an AWI in this case? In the latest draft of R 51 (automatic catchweighing instruments) this problem is considered.

2 Whose responsibility is it to classify NAWI and AWI?

Certain verification officers and users need to know the type of weighing instrument they are using, and weighing scale manufacturers must know which type of scale to produce. A weighing instrument such as a gravimetric filling machine does not pose any classification problems in itself, however if the machine is classified as a NAWI, this may become a problem.

Specialists in various metrology services do not normally encounter problems in recognizing whether an instrument is a NAWI or an AWI, though in different countries interpretations may vary.

The last link in the chain is the user, who is not necessarily familiar with weighing technology. NAWI and AWI identification marks should therefore be clear and specific so that both the user and manufacturer engineers can understand the classifications. They are not, however, required to know the complete set of recommendations but they should understand when and why a NAWI or AWI is to be used.

It is often clear when an instrument should be an AWI, but sometimes a problem may come to light, especially if a process line using NAWI instruments is to be modernized.

3 The practical situation

Let us consider the example of a manually controlled process line, common in industrial contexts. Automation often results from the need to reduce production costs; this is relatively easy to achieve, given today's programable logic boards and intelligent weighing indicators.

In a typical process line, an operator controls the NAWI weighing instrument and indeed the whole line. After modernization, an automatic control system replaces the function of the operator. In fact, it is the operator who is "automated", not the weighing scales. Before, he or she had to check the object to be weighed and monitor the zero indicator and the equilibrium of the scale. After modernization, zero indication is automatically checked between weighings, the result is read and an automatic check is also made that the NAWI is in stable equilibrium.

4 Classification of the scales

After the process line has been modernized, there is no longer an operator but the weighing scales perform exactly the same functions as before. So should the classification really be changed? For the user, this difference is not readily understandable.

The construction engineer concentrates on the hierarchy of the automation levels. If the operator's task before was to continue the process when weighing was completed, then the automatic control should work in the same way. For the user, there is no difference and only the operator has been automated.

In the past the operator provided the process feedback from the weighing process. With NAWI this feedback is always present, but not with AWI. The AWI must have a reliable weighing result in a given time - the process does not wait for the result. This is a very significant difference and the feedback from the process should be taken into consideration by classifying the NAWI and the AWI.

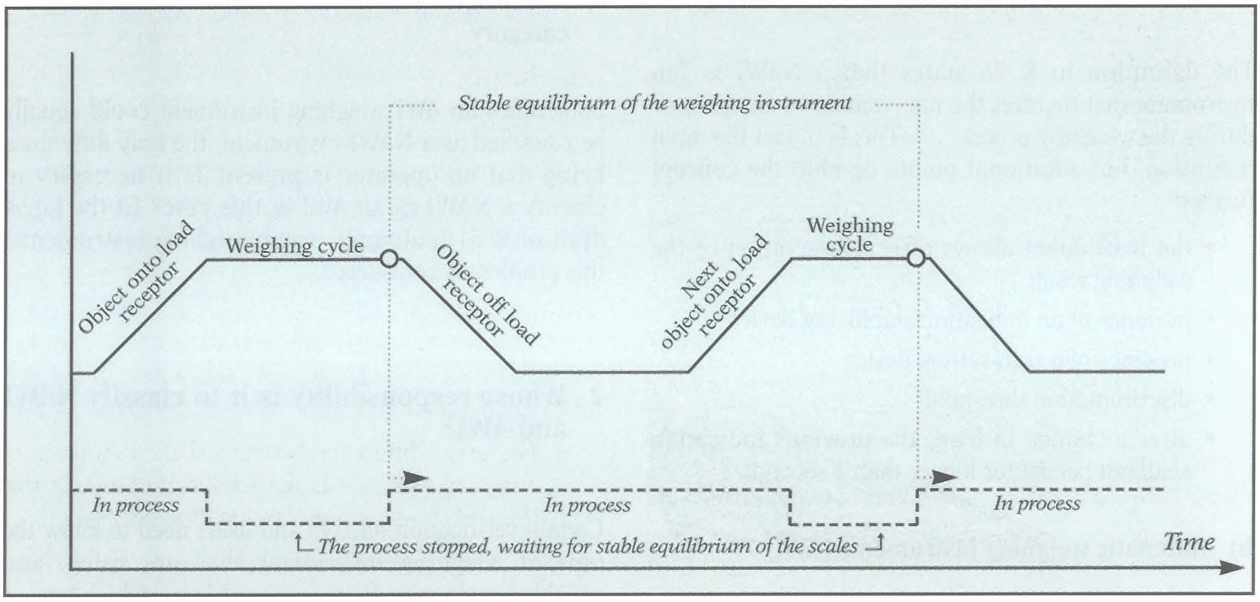


Fig. 1 **The weighing cycle for NAWI.** The process does not continue until the scales indicate stable equilibrium and the weighing result has been recorded.

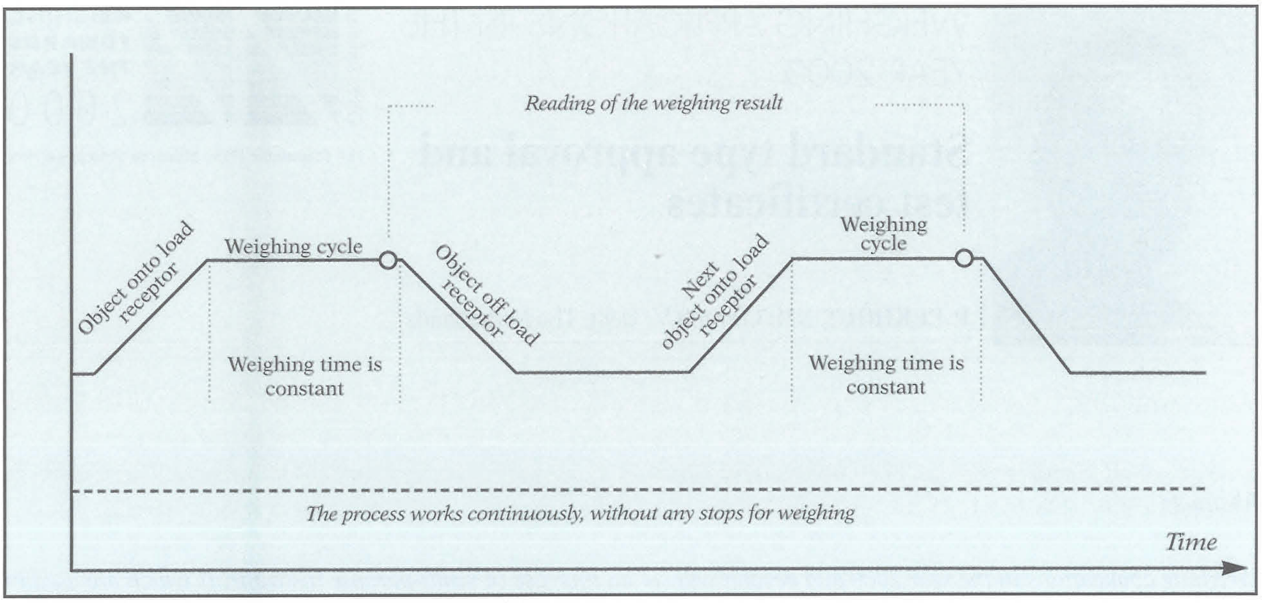


Fig. 2 The weighing cycle for AWI - the process continues without feedback from the weighing instrument.

Fig. 3 NAWI installed on a process line at OMG Kokkola Chemicals Oy (Finland)

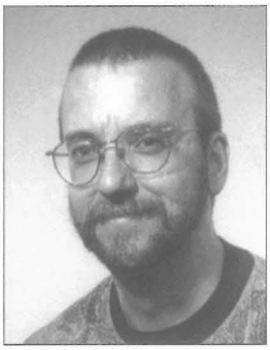
Figure 1 shows a situation for NAWI and Fig. 2 shows one for AWI. In the latter case, the process continues without any feedback from the scales; the weighing result must be used within a given period and the line only stops if a fault occurs. A number of scales of this type exist, for example automatic railway bridges, gravimetric filling machines and check-weighers. Figure 3 shows a process line installation in an environment where persons are not able to work and where high cost materials (in this case cobalt powder) are involved.

Conclusion

A problem exists when determining between NAWI and AWI; OIML working groups must deal with this point. The definitions must be easily understandable and of use to the user, to verification experts and to the manufacturers of scales.

In concluding, it is our opinion that the following two points should be considered when reviewing a NAWI / AWI definition:

- The main difference between these two types of weighing machine is the feedback obtained; this element can serve for classification purposes.
- Automatic control systems are capable of replacing operators. So the term "operator", if used in the definition, could be a person or an automatic control system. ■



WEIGHING APPLICATIONS IN THE YEAR 2000

Standard type approval and test certificates

OIML Seminar WEIGHING TOWARDS THE YEAR 2000

13–15 September 1995 Maison de la Mécanique, Paris

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Abstract

Weighing applications in the year 2000 and beyond will see an increase in multi-purpose instruments which are used in computer networks across the globe. Free programmable computer based weighing instruments will be developed to meet the increasing demands of users.

The challenge facing Certification Bodies is to find ways to make this possible, whilst guiding technological developments without hindering them. For this reason NMi has developed a new approach for type-approvals procedures, often needed before a weighing instrument can be used for legal purposes. This approach is called Standard Type Approval and Test Certificates: STATC.

The fundamental philosophy of STATC is to confine test work and documents to those characteristics of the instrument which directly influence its metrological properties.

STATC gives manufacturers improved interchangeability of modules, avoids expense and unnecessary time-consuming test work and also gives clear information on the consequences when modifications are made.

The world today is a fast moving world on the brink of discovering applications for the technology of tomorrow and implementing these applications in a wide range of instruments including weighing equipment.

The focus seems to be on combining different ideas, know how and practical use in a variety of disciplines. Key-words in this domain are:

- Maximum flexibility
- Multi purpose instruments
- Low cost
- Plug and play
- Easy use
- Inter-active
- Fully integrated in whatever other system.

The first instruments based on this concept, multi-media computers, are now sold for house hold applications. Sales of these seem to depend on how many functions the computer can combine. People want to interact with the game, hear music, see three-D pictures and still be enable to switch to a television program if the latter is more interesting.

For commercial applications, totally programmable point of sale units now combine price computing, invoicing, book-keeping, inventory and manage-3ment information modules.

The challenge facing legal metrology legislators is how to control 'legal for trade' weighing instruments in an environment where flexibility, inter-working, compatibility and multi-use are the selling points.

To clarify the above, a tangible example is given below.

Imagine a shipping company with offices around the world. Goods are shipped from A to B and the shipping price is based on weight. In every office the company has a computer based weighing scale which sends the weighing information to orbiting platform 'Freedom', from which data is gathered and processed and an invoice with individual weight values is sent to the customer. Clearly the whole system is used for trade purposes.

What should be certified and therefore tested? A local printer connected to each computer in every office can of course be used to answer this question, but for the sake of argument one wonders how to define the different modules in the system from a Weight and Measures point of view if no local printer is present.

To answer this question NMi has developed a system that is rigid in structure but not in application:

Standard Type Approval and Test Certificate, STATC. The main objective of STATC is to assign relevance types to properties. The following types are distinguished:

a. ***Essential:*** properties directly determining metrological performance;

b. ***Conditional:*** properties having a slight or no influence on metrological performance, but nevertheless subject to specific specifications;

c. ***Non-essential:*** properties having no influence on metrological performance and not subject to specifications other than general specifications.

These three types have different consequences for the manufacturer and the user.

1. If a property is ***essential*** then tests are performed and if an essential property is changed then re-testing is necessary;

2. A ***conditional*** property should also be tested but a conditional property may be changed, provided that modifications or replacements do not conflict with the description in the official certificate;

3. A ***non-essential*** property does not need to be tested and may be changed or replaced as long as general specifications are respected.

If we apply STATC to the application given in the example above it becomes evident why a local printer is an easy solution. Since the print-out on the local printer gives the possibility to check the invoice, the invoicing configuration is non-essential: i.e. the configuration has no influence on the metrological performance of the instrument and is only subject to general specifications. This also means that parts in this non-essential configuration can be replaced or modified in line with the wishes of the user and re-testing is not necessary.

If there is no local printer the following applies for the hardware involved:

a. The weighing instrument is of course an essential part because it determines metrological performance;

b. Peripheral devices, i.e. computers, modems, printers etc. are conditional parts in so far as they are involved with data-handling and can have an influence on the data because although they have a slight or no influence on metrological performance, they are for the time being subject to specific specifications:

- Weighing information should be presented according to requirements;
- Weighing information should be protected against manipulation by the user;
- Peripheral devices such as computers, modems and printers should not influence the weighing results (peripheral devices should have a limited susceptibility to disturbances but react to significant faults).

c. Peripheral devices connected to the network which are not involved with data-handling are non-essential.

Thus both the weighing instrument and the peripheral devices must be tested. However by assigning 'conditional' relevance to the peripheral devices it is possible to gain some flexibility in the system. Since conditional parts have only a slight or no influence on the metrological properties of the weighing instrument, they can be replaced by other tested peripheral devices without re-testing.

Tests on the complete system are of course not possible. Indeed the way it is described at the moment one could be under the impression that the orbiting platform 'Freedom' itself should be tested. (This might prove difficult because it is not likely that the European Space Agency or NASA would allow this).

Furthermore if the system is tested as a whole two practical problems occur:

- Who will make the application?
- Who is going to pay for what?

To avoid this problem, modular testing has been developed. To put orbital platform 'Freedom' to one side for a moment, a more down to earth example of modular testing is given in the form of a non-automatic weighing instrument which consists of the following modules:

- Load cell
- Analog data processing unit
- Digital data processing unit
- Display
- Power supply.

The load cell and analog data processing unit are essential parts since both determine the metrological properties of the instrument. This means that if modifications are made, these parts are re-tested and a revision of the certificate is issued. The requirements for these modules are at the moment defined in OIML R 60 and in the European Union in the WELMEC 'Guide for testing of indicators'.

The digital data processing unit, display and power supply can be either essential, conditional or non-essential, depending on the test results and the functionality of the units. For example if the display only consists of a LCD screen then general specifications such as display heights should be followed but the LCD screen has no influence on the weighing result and is therefore non-essential.

This opens a wide range of perspectives for manufacturers of weighing instruments because now they can buy displays around the world without the need to control them, which legal metrology would normally require.

If during the design of the instrument the functionality and performance of the modules are such that optimum use is made of the definitions given in STATC for essential, conditional and non-essential types, the only essential parts might be the load cell and the analog data processing unit; the rest could be considered non-essential. This means that the manufacturer can supply the power supply, the display and the data processing unit the customers wants. It can even mean that the digital data processing unit can be updated from a 486 micro-processor to a Pentium or to a P6 without the need for re-testing.

A similar approach can be adopted for software. The focus in this exercise is on software for non automatic weighing instruments. This consists of many modules, i.e.:

- Weighing module;
- Operating system;
- Data transmission module;
- Management data collecting module;
- Bookkeeping module.

The weighing module is evidently essential since it determines the metrological properties of the instrument. The data transmission module in this example is conditional because the transmission of weighing data for legal trade is subject to specific requirements:

- Weighing information should be presented in line with the requirements;
- Weighing information should be protected against manipulation by the user.

The operating system, management data collecting and bookkeeping modules are subject to general specifications but they have a slight or no influence on the metrological properties and are therefore non-essential. This has the following consequences under the conditions give by STATC:

1. Only the weighing and data transmission modules have to be tested.

2. The other modules do not have to be tested and can be replaced. This makes it possible, for example, for a user to update his operating system from Windows 3.11 to OS/Warp or from Windows 95 to Operating System 2000.

The fundamental philosophy of STATC is clear: to confine test work and documents to those properties of the instrument which directly influence metrological properties, or to those properties which have to comply with specific requirements.

With this in mind the data-flow of weighing information can be considered in more detail. As mentioned before, in the year 2000 the majority of data transmission will be via integrated networks. Weighing data will flow through computers, modems, telephone lines or optic fibers, net-servers and communication satellites until it finally arrives at its destination: orbiting platform 'Freedom'.

The flow of the data is not known since it will follow the path of least resistance. That means that all connecting instruments should be tested since every connecting computer can handle weighing data.

With STATC the following approach could also be used: the data transmission module in non-automatic weighing instruments scrambles the weighing information, which the receiving computer unscrambles and presents on the terminal. Communication is protected by means of error correction and failure recognition methods.

Theoretically, once weighing information is scrambled and communication errors are detected and corrected by the receiving party, it can be assumed that equipment between the sending and receiving instruments will not influence the metrological properties and is therefore only subject to general specifications because:

- Manipulation of the weighing information is detected and acted upon, and
- Changes through disturbances are either corrected or acted upon by the receiving computer.

This makes the equipment between the sending and receiving computers non-essential and theoretically opens up the possibility to connect the computer based weighing instrument to the Internet and indeed obtain a print-out on board the orbiting platform 'Freedom' without the need to test all the hardware involved or the installation of local printers in every office.

Conclusion

STATC NMi avoids much expensive, time-consuming and often unnecessary test work, provides optimum system flexibility and allows free interchangeability of non-essential modules, or subjective interchangeability of conditional and essential modules.

In the light of the European Union metrological Directive (currently under discussion) STATC is being developed for all measuring instruments - mass flow meters, automatic weighing instruments as well as breath analyzers and pressure meters.

STATC NMi answers questions about the measuring applications of the future and lays down requirements for configurations which fulfil the demands of tomorrow.

However much work still needs to be done to enable manufacturers, legal metrology legislators, different OIML Recommendations and STATC to harmoniously develop the infrastructure for weighing in the year 2000 and beyond.

These tasks include developing requirements for modules, defining conditions under which modules can be interchanged and determining the specifications to be mentioned in the certificate to make the correct connection.

Back to the challenge for the Certification bodies: how can 'legal for trade' weighing instruments be controlled in an environment where flexibility, inter-working, compatibility and multi-use are the selling points?

NMi hopes that this paper can contribute to the discussions and clear the way to a bright, new future. ■

ISO 9000 IN THE REPUBLIC OF CUBA

Accreditation of the INIMET testing laboratory - implementation of ISO 9000 and ISO/IEC Guide 25

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ISO 9000 Forum Application Symposium in Havana, 12—14 October 1994.

Abstract

The Metrology Research Institute Testing Laboratory (INIMET), which is affiliated with the National Office for Standardization of the Republic of Cuba, was established in the 1970's with the objective of carrying out tests for the evaluation and approval pattern of measuring instruments used in the country, as part of the control of measuring instruments importation and national production.

Introduction

The first steps focused on defining the content and scope of the four objectives cited below and on creating the methodological, organizational and technical foundation for their fulfillment.

The first stage included the metrological evaluation - a theoretical analysis of the technical and metrological characteristics of the pattern to find out whether or not the usage requirements were met.

In the 1980's, experimental work began with parametric tests involving about 30 physical quantities and parameters, using the INIMET set of standard measuring instruments and measurement systems; later, tests on electrical safety, ambient humidity and temperature were added, ensuring more complete information about the general behavior of a pattern under different operating conditions.

As a consequence a wide variety of tests were initially made on measuring instruments and later on conventional and even high technology medical equipment, mainly to approval pattern. Other products also tested include laboratory equipment, household appliances and teaching devices.

All organizational, technical, material and human related aspects which influenced the above activities were played up so as to ensure the quality of our services. We applied the "Quality Assurance" concept, which was introduced in the late 1980's by Ishikawa and Yamaguchi, among others.

However, despite our advances, we realized that our quality level was not demonstrated; it was only a *potential* because there was no documentation, quality system or quality manual linked to it.

Objectives:

- Ascertain the legitimacy of the technical and metrological characteristics stated by the manufacturers, thus guaranteeing the uniformity and precision of measurements;
- Reduce the wide variety of measuring instruments;
- Guarantee the metrological assurance of these instruments;
- Ensure the necessary technical level and quality of measuring instruments manufactured in Cuba.

Development

Cuba's implementation of NC-ISO 9000 series standards on quality management and quality assurance in the early 1990's (particularly NC-ISO 9004-2 specific for all kinds of services) helped us understand that service quality is one of the key elements for the proper functioning of any organization.

The use of these standards in our laboratory allowed us to further our development from the conceptual and documentational viewpoint, since we not only did our best to fulfill the necessary requirements to obtain reliable results, but also tried and succeeded in demonstrating it.

NC-ISO/IEC Guide 25 on "General Requirements for the Competence of Calibration and Testing Laboratories" was also assimilated, a step towards the accreditation of our laboratory. We have been involved in this complex task for two years now and once completed we would be able to demonstrate our technical competence and guarantee the reliability of our service.

The implementation of NC-ISO 9000 series standards and the NC-ISO/IEC Guide 25 in our laboratory enables us to elaborate and implement the quality system and quality manual.

Quality objectives were defined and focused on:

- The performance of our work with the proper scientific-technical rigor;
- The attainment of reliable results;
- Optimizing time, material and human resources for better management effectiveness;
- The safety in the reliability of information and protection of clients' rights;
- Avoiding complaints; and
- The constant raising of quality levels.

Conceiving and documenting a quality system which would enable us to achieve the above objectives and also establishing an infrastructure for recognized test activities which comply with the statements in the reference documents, meant that the following aspects (among others) had to be taken into consideration:

- Quality policy;
- Quality system;
- Personnel;
- Building and environmental conditions;
- Measuring instruments and test equipment;
- Reliability of information and protection of clients' rights;
- Nonconformities and corrective actions;
- Laboratory management documentation and register;
- Activities related to test objects;
- Complaints;
- Subcontracts;
- Costs;
- Quality audits and qualification.

Our work took the following direction:

1 Improvement of the work organization of management personnel, scientific-technical experts and support workers. The hierarchy of each activity and the general methods of action in the laboratory were also improved.

2 Specialization of tests according to guidelines established by ISO, OIML, IEC and other international organizations.

3 In the case of non reproducible tests, the establishment of a subsystem allowing for the definition of services, quality related responsibility and authority at each work stage, a process that was divided into two phases: one related to personnel and the other linked to services and their interrelation with the personnel. These two phases included the following work stages:

- Meeting with the client to obtain preliminary information on the requested service;
- Selection of the technical testing area and the specialist in charge of the work;
- A work session to obtain detailed information on the requested service and reach an agreement with the client;
- Reception of information, documents and test objects;
- Implementation of the documental and experimental work phases; and
- Information consolidation, processing of results, conclusions and reports.

4 Establishment of the facilities for controlling environmental parameters.

5 Improvement of the subsystem for test objects reception, location, identification and maintenance.

6 Organization, coding and filing of test programs prepared thus far, which include performance test procedures.

7 Improvement of secretarial management, separating archives from specialized documental information and general information.

8 Arrangement of a personal file per worker, containing information concerning his curriculum.

9 Establishment of a quality control subsystem for the different activities of the laboratory; for instance, the quality control subsystem for non reproducible tests, which specifies the following quality control indicators:

- Scientific-technical rigors;
- Development of experimental work;
- Information analysis;
- Decision-making;
- Test report writing;

- Work performance at foreseen time; and
- Absence of non-conformities and/or complaints.

Each of these indicators included information about the analysis during evaluation. For instance, when evaluating the scientific-technical rigor, the following aspects should be observed:

- Level of theoretical and practical preparation for the test;
- Use of current techniques;
- Content of the test program and the agreement with the head;
- Organization of work; and
- Preparation of the expedient.

When evaluating the way in which the experimental work took place, the following aspects should be analyzed:

- Control of all measuring instruments, testing equipment and other devices necessary for the work;
- How measurements and statistics or mathematical processing are controlled; and
- The use of registers recommended by international organizations to gather information based on results.

Another example is the content of the analysis of the indicator about the elaboration of a test report, in which coherence and objectivity are evaluated, as well as the use of the standardized format.

10 Work was also carried out regarding the determination of interaction with key interfaces, subcontracts and costs and, finally, the creation of the laboratory quality manual.

The implementation of NC-ISO 9000 series standards and NC-ISO/IEC Guide 25 in our field has allowed us to improve the quality of our laboratory services and increase our technical competence. Some of the benefits obtained are:

- Better organization of the laboratory;
- Proper development of the scientific-technical and managerial laboratory activities;
- Elimination of improvisations, thus reducing non-conformities and complaints;
- Better treatment of the specialized and general laboratory information;
- Faster information retrieval;
- Proper control and rapid obtaining of information concerning the working environment, measuring instruments and test equipments; and
- Rapid selection, better identification and greater conservation of test objects.

Conclusion

It is worth noting that during this process, there was a gradual and dynamic interaction between the conception and creation of the different subsystems, and the briefing of personnel and its implementation. This interaction was of such a kind that in practice almost all of these could be identified. ■

METROLOGICAL INFRASTRUCTURES

METROLOGICAL ACTIVITIES IN DEVELOPING COUNTRIES

23–24 OCTOBER 1995
BEIJING, PEOPLE'S REPUBLIC OF CHINA

Goals and approaches for legal metrology development programs

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Abstract

The following considerations arise from the experiences gained during the metrological cooperation programs run by the French institutions over the past years, and from the orientations and schemes resulting from the last calls for tenders on metrology and legal metrology issued by international development organizations. The main purpose of this paper is to show that legal metrology development programs must be carefully studied in order to meet both the needs of the countries and/or regions and also the conditions for their success. The examples of programs shown in this paper should not be considered as universal and definitive schemes, but rather as examples of the different approaches that can be proposed. Each development program must be studied and elaborated after a thorough discussion with the countries concerned.

I Why is legal metrology necessary?

All countries have (or plan to have) a Weights and Measures Act, and engage in legal metrology activities. Most regions (NAFTA, Europe, Asia Pacific, etc.) develop a cooperation in legal metrology. The purposes of these policies are multiple.

I.1 At national level

The main purpose of legal metrology is to ensure that the reliability of measurements is upheld in law. This principal objective may be subdivided in several sub-objectives:

Consumer protection

The most obvious objective of legal metrology is to give adequate protection to the public concerning measurements performed in the course of trade. Instruments must be of the required accuracy and reliability, they must not facilitate fraudulent use, nor be misleading. Owners of the instruments must make fair use of them. This is applicable for sales to the public, and also for trade between companies if public action is considered necessary.

Measurements in international trade

Measurements in international trade are of great importance for the economy, and often involve State to State contracts. Goods imported or exported may be for example energy products (crude oil or refined petroleum products, gas, etc.), alimentary products (cereals, meat, etc.), or water. Any discrepancies about quantities shipped or delivered concern important amounts of money and the public authorities have to deal with these measurements.

Promotion of metrology

Legal metrology is often a way of developing good measurements in the country. It starts with the obligation to use legal units (SI units), but very often in developing countries, the only calibration facilities disseminated in the field are those of the legal metrology offices. Legal metrology officers, if they are correctly trained, may be the most relevant consultants to small industries for metrological matters.

Assistance for buyers of instruments

Part of the legal metrology activity is to define classes of performance and classes of conditions of use of the instruments. This activity, which is close to standardization, provides the users with recommendations for the choice of instruments that they have to be equipped with. Even in the case that the instruments are not subject to mandatory legal control, this may give helpful guidance to the industry.

Control of imported instruments

Even the "approved type" quality conformity of instruments manufactured in a country where legal metrology services are reliable is not always certain once the instruments are imported, despite them having been submitted for OIML certification and national type approval in the country of origin. Countries which import instruments must therefore be able to control their quality.

Promotion of local instrument manufacturers

When instruments are manufactured domestically, it is not advisable to ask for type approval issued by another country. Some type approval facilities are therefore necessary for locally manufactured instruments. If the manufacturers of these instruments want to export them, it is necessary that the local type approval bodies demonstrate an adequate level of competence and reliability, both to give the necessary assistance to the manufacturer and to be recognized internationally.

I.2 At regional level

Legal metrology cooperations at regional level are growing in most areas. Their objectives may differ according to different factors, in particular:

- countries may show a comparable or a different technical level;
- countries may or may not have a policy for a single regional market.

Therefore, the goals of regional actions in legal metrology may be the following:

- To share the technical capacity of laboratories
- To exchange technical information
- To specify regional needs in legal metrology
- To appraise representation in OIML
- To simplify interregional mutual agreements
- To set up a single regional market for measuring instruments
- To develop the technical capability of regional manufacturers

II What programs are classically proposed?

Compared to this diversity of situations and needs, the cooperation programs proposed by most international development organizations adopt almost the same approach. This standard approach may be described as follows:

II.1 A classical national program

- Definition of the equipment for a national legal metrology laboratory
- Supply of equipment
- Training of staff for type approval testing
- Assistance for drafting a Weights and Measures Act
- Definition of equipment for local offices
- Supply of equipment to local offices
- Training of staff for verification of instruments

II.2 A classical regional program

- Definition of the equipment for the national legal metrology laboratories (or to be shared between the national legal metrology laboratories)
- Supply of equipment
- Joint training of staff for type approval testing
- Definition of equipment for local offices
- Supply of equipment to local offices
- Joint training of staff for verification of instruments

II.3 Characteristics of these programs

These types of programs have several advantages: they are standardized enough to be easily understood by financing organizations and to be reproduced in any country or region; they provide equipment which may be visited and demonstrated; they facilitate the work of suppliers.

However, this approach does not take into account the needs of the country, nor does it ensure the perenniality and correct use of the equipment and competencies. Several factors may affect the output of these programs:

- The Weights and Measures Act may not be adopted, may be adopted with a different scope than initially planned or may be insufficiently implemented. In this case, the risk is that laboratories set up will become redundant;
- Local manufacturers may not supply enough work to the type approval laboratories;

- Trained staff can find better salaries in private companies;
- Type approval laboratories are not usually profitable in developing countries, and their operational costs may not be financed;
- No local maintenance may be available for the laboratory equipment;
- Budgets for maintenance may be insufficient.

The conclusion about such "standardized" programs is that they develop a local offer of legal metrology services whereas on the other hand:

- the demand is insufficient;
- the economy cannot afford it;
- the technical environment is not adapted.

III Preferred approaches

It is important that these programs be adapted:

- To the goals of the national legal metrology policy
- To the needs of the country
- To the technical background of the country

This implies a preliminary analysis of these questions. Examples of approaches are given below.

III.1 Consumer protection oriented national program

III.1.1 Preliminary questions to be answered

The elaboration of a program must be based on a study of the needs of the public and of the scope and extension of legal metrology. Issues for this study are technical, economical and sociological, and require a good knowledge of the national specificities. This first step is then a qualitative study:

- What are the most commonly used instruments?
- What are their conditions of use?
- What are their insufficiencies?
- Is it a question of:
  - poor available technology?
  - education of users and the public?
  - maintenance and repair possibilities?
- Would a better technology be assimilated:
  - by users?
  - by repairers and maintenance suppliers?
- Could users financially afford better technologies?
- Could users afford maintenance costs?

III.1.2 Evaluations to be made

The second step is a quantitative study of the system to be set up:

- Number of instruments in service to be controlled for each category
- Cost and staff required for the surveillance by public officers
- Cost and staff required for a periodical verification (different time intervals possible) by public officers
- Number of instruments which should be repaired annually
- Offer of repair and maintenance (in volume)
- Competence of the repairers

III.1.3 Setting up a basic metrological background

Legal metrology cannot operate if the owners of the instruments are not technically able to maintain their instruments in good condition. The first action must therefore be to develop a suitable offer and infrastructure for the maintenance of the measuring instruments. This can be done by:

- Financial support to the repairers to buy standards and train their staff
- Setting up metrological training for repairers
- Setting up technical training for repairers
- Obligation for repairers to be registered and eventually approved
- Setting up facilities to calibrate repairers' standards

III.1.4 Organizing the control of in-service instruments

The first purpose of the control to be set up is to ensure the accuracy and correct maintenance of the measuring instruments in service. This may be organized in different ways, for example:

- Periodical verification by public officers (generally free of charge). In this case repair will be required after refusal of an instrument and
  - verification by public officers may be prescribed after repair; or
  - repair must be done by approved repairers (follow-up of repairers being assured by the local legal metrology offices).
- Mandatory periodical maintenance by agreed repairers. In this

case the role of local legal metrology offices will be:

- Surveillance of the instruments
- Follow-up of agreed repairers

The cost for the State and the cost for the users of the instruments will be different in these cases and will have to be taken into account.

III.1.5 Organizing the control before putting into service

This further step is to ensure that the instruments are suitable for use. This includes type approval and initial verification, and may be organized in different ways.

- Type approval:
  - Asking for type approval issued by foreign organizations
  - Setting up national type approval on the basis of OIML certificates
  - Setting up type approval facilities for national manufacturers
- Initial verification:
  - Asking for initial verification performed by foreign organizations
  - Setting up national initial verification for national manufacturers

III.2 Manufacturer oriented national program

III.2.1 First questions to be answered:

- Do local manufacturers work essentially for the national market?
- Does the national market require standardized instruments or specific instruments?
- Is the national market attractive for foreign manufacturers:
  - Size of the market?
  - Market prices?
  - Currency exchange?
- Are the national manufacturers technically competitive:
  - Regarding the demand of the national market?
  - For export?
- Is the quality level of their products satisfactory?
- Do they depend on imported technologies?
- Does their cash-flow enable them to invest?

III.2.2 Actions for export

- Study of the ability of manufacturers to export:
  - Technically (technology of the instruments)
  - Quality level of the production
  - Financially (commercial costs)
- Developing technical assistance to national manufacturers
  - For compliance with international legal metrology requirements (technology and quality of design)
  - For information on foreign market requirements (other requirements such as security, health, etc.)
  - For manufacturing and quality control processes
- Setting up national testing facilities:
  - Where relevant
  - Taking into account the financing of annual budgets
- Moving towards mutual recognition of the laboratories:
  - either bilaterally (laboratory to laboratory), which can be a simple and effective solution;
  - or at national or regional level (by the means of accreditation).

III.3 Regional program bound by interregional agreements

III.3.1 Defining basic national laboratories networks:

- Identification of the national laboratories to be accredited (fields and volume of activity)
- Technical evaluation of these laboratories
- Quality training and setting up of quality systems and procedures in these laboratories
- National intercomparisons if possible

III.3.2 Setting up national accreditation systems:

- Setting up and financing a provisional structure for accreditation
- Studying the definitive structure and its financing
- Studying the cost of accreditation for the laboratories
- Elaborating assessment guides
- Training of quality assessors
- Identification of technical experts for audits
- Organization of audits assisted by senior assessors from other countries

III.3.3 Starting regional cooperation:

- Setting up a regional coordinating body
- Developing guides and interpretative documents for type approval
- Developing regional intercomparisons:
  - For testing and calibration
  - For type approval examination
- Developing regional peer assessments
- Setting up regional mutual recognitions of:
  - Test reports
  - Type approval certificates

III.3.4 Interregional relations:

- Organizing liaisons with other regional coordination bodies
- Organizing or participating in interregional intercomparisons and assessments

III.4 Regional program to establish a single regional market

Two ways of promoting a single market for measuring instruments are envisaged:

- Development of international and regional approaches towards harmonization; this is being done in Europe by establishing regulations which are binding for member states and which establish free movement of industrial products;
- Voluntary harmonization by legal metrology services and mutual recognition agreements.

These two methods are not exclusive and can be complementary. Political involvement of the member states in the region for free movement is a strong incentive for legal metrology services to move towards voluntary harmonization.

An example of developing such a voluntary harmonization can be described as follows:

- Creating a coordinating body for legal metrology services (WELMEC for example)
- Exchanging information on and harmonizing test methods, interpretation of test results and examinations
- Defining common test report forms
- Organizing intercomparisons and studying a mutual recognition agreement
- Examining the technical differences in the national regulations and harmonizing them
- Organizing liaisons with manufacturers:
  - At national level by legal metrology services
  - By promoting regional organization of the manufacturers

IV Conclusion

The elaboration of a program for the development of legal metrology requires a sound knowledge of the needs of the country and of the economical and technical background. National experts then have an important role to play in the elaboration of these programs, as well as in their implementation, as they require inquiries to be made and studies to be carried out in the country which foreign experts are not qualified enough to perform by themselves, and which in any case would be too expensive.

Such programs must be elaborated and realized by a close cooperation between the national experts and consultants from other legal metrology services.

It is not appropriate to adopt programs which have been defined unilaterally by experts who are not involved in legal metrology and to run them blindly. The OIML Development Council is the most appropriate forum to discuss and compare the different schemes of action for the development of legal metrology. ■

AUTOMATIC WEIGHING

OIML Seminar WEIGHING TOWARDS THE YEAR 2000

13–15 September 1995 Maison de la Mécanique, Paris

Slow speed weigh in motion: how it has evolved and why

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Abstract

Weigh in motion or dynamic weighing systems have been around in one form or another for about forty years, however the past fifteen or so years have seen an enormous increase in the use of these devices.

The requirement to weigh road vehicles whilst on the move stems from a wide range of different applications that use vastly differing technologies; these include conventional load cells, strain gauged bending plates, capacitance mats and strips and piezoelectric coax.

Although the technology utilised in some of these devices is often cunning and effective in its own right, the accuracy of most of this equipment is of academic interest only to the metrologist.

Introduction

Weigh in motion systems fall into three main categories: high, medium and slow speed systems.

High speed systems are devices that can operate at speeds between 10 mph and 80 mph (16 km/h to 129 km/h) and which are used principally for collecting data about the vehicles that travel our highways.

In the early 1970's multiple load cells were used to measure the load on a light weight load receiver; these were inevitably expensive and subsequently installations were few in number.

These days the technology utilised in this type of scale is usually piezoelectric coax encased in a polyurethane material, or strain gauges attached to a bending plate, or capacitive mats or strips.

Connected to suitable instrumentation, typically these equipments will provide and store information on axle weights, gross weight, vehicle class, speed, length of vehicle, and the distances between travelling vehicles.

The accuracy of this type of system is not (as one might imagine) particularly high. The environment in which they have to work is not an easy one of course: roads are not flat and wheels are not round, contrary to popular belief. This results in considerable low frequency vibration in the vehicle being weighed which accounts for the relatively low accuracy produced by this type of weighing system.

However gross weight accuracies of ± 10 % are achievable in certain circumstances, but axle weights will often vary between 15 % and 20 %.

Medium speed weigh in motion systems are used principally as pre-selection scales in the approaches to overload enforcement scales, sometimes called sorting scales or filter scales. These devices will use load cell technology, strain gauged bending plates or capacitive mats as the load sensing elements.

They are able to operate with accuracies between 3 % and 6 % at speeds up to 30 mph (50 km/h) given sensible approach levels.

The pre-selection scale can be a very useful device to a vehicle weight enforcement agency for *estimating* the weight of vehicles before arrival at the enforcement scale, thus enabling decisions to be made about furthermore accurate weighing of violating vehicles.

Although these applications and technologies are very interesting developments it is the intention to take a closer look at ***slow speed*** weigh in motion of road vehicles, why this technique became necessary, and how it has evolved in the age of the microprocessor.

Background

The very first slow speed weigh in motion application materialised in the mid 1950's in the USA. The Pennsylvania Turnpike, concerned about potential damage to its toll roads along with half an eye on additional revenue, decided to weigh all trucks as they approached the toll plaza, and to charge a toll according to the weight of the truck.

Some time later Weights and Measures became aware of this situation but by this time the turnpike authorities had established grandfather rights to charge trucks by weight, and they were able to continue this practice. Other states were not permitted to follow this course of action after it had become known to Weights and Measures as a legal for trade application.

Practicalities

A decade and a half later and without any prior knowledge of the Pennsylvania application, I was privileged to lead a group of young engineers in a project which at first sight seemed to be a relatively simple static weighing requirement.

The objective was to design and build a system that would weigh the axle weights of heavy goods vehicles for enforcement of the new axle overload legislation through the British Courts. An example of a design is given in Fig. 1.

The task before us was to prove far from simple. The problems we faced were generated by the very objects we were trying to weigh, the individual axles of multi-axle heavy goods vehicles.

We found that using an axle weigh-bridge to weigh individual axles by stopping each axle one at a time on the load receiver produced large and widely variable errors on most vehicles with more than two axles. Our test criterion was to compare the summated axle weights with the gross vehicle weight indication from a full size certified weighbridge.

We went to great lengths to keep the approach and the exit to the axle weigher flat and level but the variations in repeatability were still unacceptable.

The basic difference between two axle vehicles which we were able to weigh within the required tolerances and multi-axle vehicles that were causing us problems was the vehicle suspension.

Multi-axle vehicles incorporate compensating systems on the closely coupled axles; when steel spring suspension is used these axles are coupled together by a load transfer mechanism.

What we were experiencing was a transfer of load within the compensated axle system as the vehicle was brought to a halt. The extent of the transfer of load was a variable, dependent upon the type of suspension, its age and condition, how hard the brakes were applied to bring the vehicle to a halt, and the load on the vehicle itself.

We had identified that stopping and starting the multi-axle vehicle between each individual axle weighing was the source of the poor repeatability and subsequent summation in accuracy. If stopping and starting the vehicle was the problem perhaps we should try weighing the vehicle without stopping each axle on the load receiver.

The results were immediately better - the break through had been made.

This was in 1973, four years after work had begun on the project. We now faced the task of turning our research into an acceptable product, but the more difficult task was convincing a sceptical Ministry of Transport and the even more sceptical County Weights and Measures Officers that we could weigh heavy goods vehicles more accurately on the move than we could if they were stationary.

This task proved to be as difficult as solving the weighing problem itself.

Eventually a trial program was compiled by two County Trading Standards Departments and Ministry of Transport engineers. Field trials began in 1974 on weighing road vehicles of every possible type, including a few that were not usually found on the highway.

By 1978 the authorities were satisfied that the dynamic axle weighbridge, as it was then called, would meet their requirements to weigh axle weights and gross vehicle weights of goods vehicles sufficiently well to prosecute violators through the British Courts of Law.

Fig. 1 General view of an integrated dynamic axle weigher. A single-axle load receptor is situated on the apron; the latter serves to minimize level variations since a flat weighing zone is vital to obtain good performances in this type of measurement.

In September of that year a Statutory Instrument came into effect within the Road Traffic Act that permitted the use of dynamic axle weighbridges for enforcement of the over load legislation.

Equipment was installed in weigh stations alongside major roads and work began on enforcement. Because there was little experience of this type of equipment in the field Weights and Measures Officers decided to verify the calibration of the equipment every six months.

The small size of the load receiver and the 20 tonne capacity of the system meant that periodic dead weight calibration in the field would be a difficult task, and in some cases a dangerous exercise.

A practical solution to verification was applied using three loaded heavy goods vehicles of known weight.

Once the equipment had been verified the enforcement officers were able to start their task of tracking down axle overloads. In addition to the obvious dangers to road safety that overloaded vehicles create, axle overloads are responsible for the premature failure of our road systems. The cost of repairs to these roads is an enormous burden on the taxpayer - almost 400 million pounds sterling per year in the UK. The cost to industry in the delays road repairs produce is almost incalculable.

Over the next seven years, 60 enforcement weigh stations incorporating dynamic weighbridges came into operation in the United Kingdom. These were manned by a team of traffic examiners, trading standards officers and the police.

There were also secondary benefits from this type of weighing operation not previously recognised. The limitations imposed by conventional weighbridge characteristics no longer applied. Vehicle length was not a limitation, the longest vehicles could be weighed with ease one axle at a time. See Fig. 2.

The gross vehicle weight measurement was not restricted by the capacity of the weighing platform because of this method of weighing individual axles. Very heavy vehicles on ten or twelve axles with gross weights of 100 tonnes or more could now be dealt with like any other goods vehicle. And most vehicles could be weighed in less than 30 seconds.

In the early 1980's dynamic weighing began to catch on abroad in countries such as Brazil, Chile, Hungary and Belgium and later on at the Hong Kong - China border crossings.

The revenue from fines for overloading at the eighteen Hungarian border crossings paid for the equipment and installation within three months of becoming operational.

In the UK enforcement using dynamic weighing machines had gone without a hitch until the EC Council Directive 90/384/EEC came into effect in July 1992. At this time

Fig. 2 **Different types of European vehicles that can be weighed - transfers of load within compensated axle systems constitute an important factor relating to the achievable accuracy of WIM systems.**

the enforcement agencies began to ask the question, will it now be necessary to have this equipment approved under the new non automatic regulations.

Up to this time dynamic weighing systems were approved under the UK Road Traffic Act 1978 and not under the Weights and Measures Act as machines for use in trade were approved.

A new debate arose around this equipment: did it fall within the non automatic regulations, or was it in fact an automatic machine, as it certainly fulfilled the criteria which applied to many automatic weighing machines.

Council's opinion was pursued by the National Weights and Measures Laboratory at Teddington, which concluded that this device was in fact an automatic weighing machine.

One British manufacturer had however taken the unusual step of pursuing non automatic approval via the Netherlands Measurement Institute where all of the environmental, stability and static accuracy testing was taking place.

The subsequent EC type approval certificate number T2277 was issued on 18th November 1993 permitting the use of the machine in static mode for trade within OIML class III and IIII.

Currently there is no provision to prescribe weighing systems to weigh road vehicles in motion within the OIML Recommendations[1].

It was therefore decided to approach The National Weights and Measures Laboratory at Teddington to pursue UK trade certification within the national rail weighing in motion regulations.

[1] *Editor's note: OIML technical subcommittee TC 9/SC 2 is currently working on the first committee draft relevant to in-motion road vehicle automatic weighing instruments. See OIML Bulletin Volume XXXVII no. 3 July 1996, p. 46).*

We believe that this was the first time that a trade (as distinct from an enforcement) approval had been considered by a national Weights and Measures laboratory for an automatic road weigh in motion machine. The necessary tests were agreed and successfully concluded. Certificate number 2309 was issued to Central Weighing Ltd on 28th April 1994.

This application brought forward a great many queries and questions, not least of which was the accuracy which might be achieved by equipment of this type. OIML Recommendation R 106 *Automatic rail-weighbridges* prescribes four accuracy classes: 0.2 %, 0.5 %, 1 % and 2 %.

There were already many Central Weighing Supaweigh systems installed and working, so the capability of the machine was confidently known by the manufacturers. It was felt that an initial verification accuracy of 0.5 % would be appropriate with an in-service accuracy of 1 %.

Other questions which materialised during the approval process were the size of the division, the scale length and the minimum and maximum vehicle weights, all of which are clear cut issues to the metrologist familiar with single draft static weighing techniques, but not so straight forward when weighing multi-axle road vehicles one axle at a time to establish a gross vehicle weight.

The size of the division needs to be as small as practicable in order to achieve the best summation accuracy of the axle weights of the vehicle. Division size is also important in achieving the best gross vehicle weight accuracy when weighing smaller vehicles.

The scale length of the weighing instrument is not at all related to the maximum vehicle weight. A vehicle could have two 5-tonne axles or six 10-tonne axles.

The most important aspect of any approval after the specification criteria have been established is in the verification of that specification as new and in service.

This is a device that is intended to weigh the gross weight of goods vehicles, so why not take a prescribed selection of goods vehicles with known weights emanating from a single draft weighbridge of known accuracy and compare the results, as is the practice within the OIML R 106 regulations. This procedure could be performed several times to confirm the repeatability and the gross vehicle weight accuracy.

The UK pattern approval adopted the enforcement verification practice established in 1978. This consists of nine runs across the automatic weighbridge with three types of vehicle, including a 2-axle rigid vehicle, a 4-axle rigid vehicle and a 5-axle articulated vehicle with a tri-axle semi-trailer. These vehicles constituted a satisfactory cross section of axle spacings as well as a wide range of varying axle weights. All of these vehicles were to be loaded to a level approaching their maximum gross weights.

The debate regarding the approach and exit levels referred to in the approval as "aprons" was an obvious consideration in the wording of the approval, and a tolerance level was included in the specification. The reason for this inclusion is purely historic; all past approvals for enforcement or for trade rail weigh in motion systems have included some form of level specification.

Good flat level aprons are vital to the accurate performance of these axle weighing systems and any manufacturer "worth his salt" will understand what has to be achieved in level terms in order to meet the verification criteria. If the levels are not sufficient, the verification will fail.

Why then should the verification procedure not be the sole factor to determine if this machine in this environment is fit for trade within the regulations or not.

It is a fact that many enforcement machines have been verified within specification and have then been taken out of service because the survey of the apron approaches has shown up some minor area outside of the level specification.

It is also a fact that surveying technology at this level is less accurate than the weighing technology under review. There are numerous examples of two survey teams getting widely different results from the same site.

The site is an integral part of the overall system and I would urge authorities considering any future approvals to rely on the verification procedure to decide if the system is within its specification, rather than surveyors using instruments often of unknown accuracy.

What will these dynamic, weigh in motion, automatic road weighbridges bring to industry and commerce when an approval is granted?

They will bring trade weighing within the reach of many who have previously been unable to afford or justify the cost of a full size single draft weighbridge, with all the appropriate savings and safeguards to both supplier and consumer that accurate weighing brings.

The sale of sand ballast and a wide range of bulk materials can now be conducted across an accurate weighing device instead of comparing a mark on the side of a vehicle body with the level of product in the vehicle.

Drivers can be paid for the product they collect or deliver instead of by the load, which previously left the employer dependant on the driver discharging the entire load after each journey.

Toll plazas can be equipped with dynamic automatic road-weighbridges approved for trade, thereby providing an equitable means of charging goods vehicles by the weight they impose on the road system.

The microprocessor has had a great effect on the weighing machine in general, and in particular in this application by ensuring the high level of measurement accuracy now achievable.

Automatic road weighbridge a year down the line

Since the UK approval for automatic road weighbridges came into operation in 1994 many organizations have taken advantage of the benefits of this type of equipment. One such organization is The Dover Harbour Board.

The Port of Dover is busiest port in the UK and is the major link with Continental Europe for heavy goods vehicles. There have been three generations of dynamic weighbridge installed in the port, the first of which was installed in 1974 as part of the initial trial of this type of equipment set up by The Department of Transport. Upgrades of the first unit have had a continuous presence in the port ever since. These units were not approved for trade but were used for enforcement of axle load and gross weight limits on goods vehicle travelling from Europe.

The Dover Harbour Board has numerous trade weighbridges in the port which enable goods vehicles to be weighed prior to loading onto roll-on roll-off ferries; this is a UK safety requirement following the disastrous sinking of the Herald of Free Enterprise in the English Channel in the mid 1980's.

The new trade approved automatic road weighbridge installed by Central Weighing Ltd. provides additional benefits to the port with its ability to weigh excessively long vehicles and vehicles with very heavy loads. Ferries can take heavy loads but it is important to know what the gross vehicle weight is in order to position it correctly on board.

Loads such as heavy plant and machinery are often calculated prior to transportation because often there is not a weighbridge with the capacity to weigh this kind of load. The experience of the enforcement agencies using dynamic weighbridges has shown that calculating the load can be very far from the actual weight. Often the carriage of the load is charged by weight so not unnaturally the calculation will sometimes be on the low side.

The system is able to weigh both outgoing and incoming goods vehicles and uses a load receiver 3 m wide and just 0.7 m long in the direction of vehicle travel. A cable connects the load receiver to a digital instrument which drives a ticket printer and a large remote external display.

The latter may be viewed by the goods vehicle driver during the weighing process. As each axle passes over the load receiver the weight of that axle is displayed and held on the display until the next axle is weighed. In this way the driver is able to establish if his axle loads are within the legal limits for the UK after the last axle leaves the load receiver. The display shows the gross vehicle weight and displays this for a user-defined period of time.

This facility, known as "selfweigh", is provided as a free service by the Dover Harbour Board to vehicles entering or leaving the UK.

The automatic road weighbridge also is available as a public weighbridge for traffic within the customs controlled area. A ticket will be printed with the necessary tare, gross and net weights as these are available. When used as a public weighbridge the Dover Harbour Board makes a small charge for this facility.

The equipment was installed in the port in June 1995 and was verified by Kent County Trading Standards Department in that month. Kent trading standards officers have been verifying this type of equipment since 1974 and as a result are very capable of conducting this process without consulting with the manufacturers, even though this was the first machine of its kind in the county approved for trade.

On 11th June 1996, one year after initial verification, a trading standards officer visited the port. Weighbridge tickets for the gross weight of 3 vehicles were obtained from a single draft trade weighbridge within the port which had just been verified by deadweights, and verification took place.

The results of the verification can be seen in annexes 1-3.

The accuracy specification for this instrument is 0.5 % as new and 1 % in service. It can be seen from the results that all 3 vehicles fell well within the accuracy specification for a new installation. The mean errors for gross weight measurements did not exceed 0.27 % on all three vehicles.

It is worthy of note that this is a hard working machine installed in the UK's busiest port into which come heavy goods vehicles from Continental Europe where in some countries vehicles with gross weights of 44 t can legally operate.

In its first year of operation at this site this machine has proved to be a robust device capable of constant use under maximum vehicle loading with excellent long term stability.

There are now over 20 such units installed and working as trade approved automatic weighbridges.

Conclusion

A summary of the benefits provided by such a machine approved for trade use is given below.

- The hardware of the automatic road weighbridge is inexpensive compared with more conventional equipment.
- The software can be configured to suit any type of application, with the necessary approval.
- As its name implies, it is automatic and requires no operator - the load receiver is simply driven across to produce axle and gross vehicle weights.
- The automatic road weighbridge is compatible with AVI (Automatic Vehicle Identification) equipment, and is a natural partner for this type of system.
- Installation is simple and less costly than most pit based weighbridges.
- Very heavy loads can now be weighed easily and quickly; high capacity single draft weighbridges are very expensive to install and are few in number.

This machine opens up for the first time a wide range of weighing applications that will benefit industry, commerce and the consumer. It will make those who abuse our environment by carrying more load than they are entitled to on our highways pay for that privilege.

The transition of this type of automatic road weighbridge from overload enforcement to legal for trade approval is surely an important step forward in weighing towards the year 2000. ■

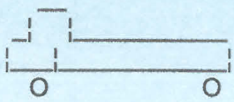
Annex 1

Certificate of Accuracy Dynamic Axle Weighbridge

Date 11th June 1996 **Inspector** Walkden **Location** Dover E Dock

Registration No. E71 TKN **Compensated Axles** No

Axle Layout Diagram



Load Sand

Particulars of Static Weighbridge Dover Harbour Board No. 2

Static Weight Recorded 15,460kg **Distance from Weighbridge** 1/2 Mile

Weather Conditions Breezy & Misty **Result** Pass

Test	Digital Readout / Printout						Static Gross Train Weight	Error kg	Position on Plate L, R, C
	Axle Number								
	1	2	3	4	5	6			
Static	XXX	XXX	XXX	XXX	XXX	XXX	15.46	XX	XXX
Run 1	6.41	9.11					15.52	60	C
Run 2	6.38	9.09					15.47	10	C
Run 3	6.38	9.10					15.48	20	C
Run 4	6.39	9.11					15.50	40	C
Run 5	6.43	9.10					15.53	70	C
Run 6	6.39	9.13					15.52	60	R
Run 7	6.38	9.11					15.49	30	R
Run 8	6.40	9.12					15.52	60	L
Run 9	6.38	9.10					15.48	20	L
Run 10	Fast								
					Maximum Permitted Error			80	

Manufacturer Central Weighing Ltd **Serial No.** 3688

Signed M R Walkden **Date** 11th June 1996

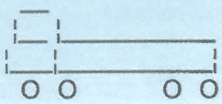
Annex 2

Certificate of Accuracy **Dynamic Axle Weighbridge**

Date 11th June 1996 **Inspector** Walkden **Location** Dover E Dock

Registration No. D825 OKP **Compensated Axles** Yes

Axle Layout Diagram



Load Sand

Particulars of Static Weighbridge Dover Harbour Board No. 2

Static Weight Recorded 30,000kg **Distance from Weighbridge** 1/2 Mile

Weather Conditions Breezy **Result** Pass

Test		Digital Readout / Printout					Static Gross Train Weight	Error Error kg	Position on Plate L, R, C
			Axle Number						
	1	2	3	4	5	6			
Static	XXX	XXX	XXX	XXX	XXX	XXX	30.00	XX	XXX
Run 1	7.42	6.37	8.19	7.99			29.97	30	C
Run 2	7.44	6.37	8.25	8.01			30.07	70	C
Run 3	7.44	6.38	8.25	8.01			30.08	80	C
Run 4	7.42	6.38	8.23	8.02			30.05	50	C
Run 5	7.42	6.40	8.22	8.00			30.04	40	C
Run 6	7.44	6.38	8.25	8.00			30.07	70	R
Run 7	7.41	6.35	8.22	7.98			29.96	40	R
Run 8	7.40	6.42	8.25	8.01			30.08	80	L
Run 9	7.41	6.37	8.25	8.00			30.03	30	L
Run 10	Fast								
					Maximum Permitted Error			150	

Manufacturer Central Weighing Ltd **Serial No.** 3688

Signed M R Walkden **Date** 11th June 1996

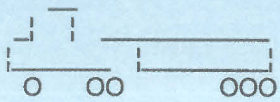
Annex 3

Certificate of Accuracy   Dynamic Axle Weighbridge

Date 11th June 1996   **Inspector** Walkden   **Location** Dover E Dock

Registration No. A14 CPH   **Compensated Axles** Yes
Tractor Scania
Trailer Crane

Axle Layout Diagram



Load JCB Excavator

Particulars of Static Weighbridge Dover Harbour Board No. 2

Static Weight Recorded 31,700kg   **Distance from Weighbridge** 1/2 Mile

Weather Conditions Breezy & Misty   **Result** Pass

Test	Digital Readout / Printout						Static		
							Gross	Error	Position
			Axle Number				Train	kg	on
	1	2	3	4	5	6	Weight		Plate
									L, R, C
Static	XXX	XXX	XXX	XXX	XXX	XXX	31.70	XX	XXX
Run 1	6.20	6.38	4.49	4.91	4.90	4.90	31.78	80	C
Run 2	6.19	6.35	4.50	4.91	4.90	4.90	31.75	50	C
Run 3	6.20	6.35	4.49	4.90	4.89	4.90	31.73	30	C
Run 4	6.21	6.36	4.48	4.91	4.90	4.90	31.76	60	C
Run 5	6.21	6.37	4.47	4.91	4.89	4.90	31.75	50	C
Run 6	6.20	6.37	4.45	4.90	4.89	4.90	31.71	10	R
Run 7	6.12	6.38	4.45	4.90	4.89	4.90	31.73	30	R
Run 8	6.22	6.39	4.46	4.91	4.90	4.90	31.78	80	L
Run 9	6.20	6.33	4.47	4.92	4.90	4.91	31.78	80	L
Run 10	Fast								
					Maximum Permitted Error			150	

Manufacturer Central Weighing Ltd   **Serial No.** 3688

Signed M R Walkden   **Date** 11th June 1996

activities OIML activités

MEETINGS

REUNIONS

TC 8/SC 7

Gas metering

Secretariat: Belgium

The Belgian Metrology Service hosted a meeting of OIML TC 8/SC 7 which was held on 10–12 June 1996 in the *Maison du Gaz Naturel* headquarters of the Belgian Federation of gas distributors (FIGAZ), Brussels.

Chairman: Mr R. Eggermont, Belgian Metrology Service

Participation: 8 delegates representing 6 P-member countries and FIGAZ; Ph. Degavre, BIML.

Main points

A working draft on metering systems for fuel gas had been prepared by the secretariat in close cooperation with the Belgian Federation of gas distributors; this was distributed in April 1996. The main objective of the meeting was to discuss the principles of this draft, in particular the following points:

- Scope and structure of the draft (does it constitute a good base for future work?)
- Definitions
- Maximum flow capacity of the measuring system ($Q_{max} \geq 100$ m^3/h)
- Requirements and test procedures for gas-volume electronic conversion devices, which should be included in the draft. They should be consistent with the requirements and tests drafted by CEN/TC 237/WG 4.
- Vehicle filling stations. These systems should be considered in a separate chapter of the draft. Appropriate requirements and test procedures will be developed by the secretariat.
- Maximum permissible errors. The secretariat prepared a preliminary Table divided into 3 accuracy classes A, B and C, which gives the MPES for the increments of temperature, pressure, density, calorific value, compression factor and volume.
- Consistency of this draft with other Recommendations, Standards (ISO, CEN) and liaisons to be established for future cooperation in this work.

The next meeting of TC 8/SC 7 is expected to be held on 10–12 March 1997 in Brussels.

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TC 8/SC 7

Mesurage des gaz

Secrétariat: Belgique

Sur invitation du Service belge de Métrologie, le sous-comité technique OIML TC 8/SC 7 a tenu une réunion du 10 au 12 juin 1996 à la Maison du Gaz Naturel, siège de la Fédération belge des distributeurs de gaz (FIGAZ) à Bruxelles.

Président: M. R. Eggermont, Service belge de Métrologie

Participation: 8 délégués représentant 6 pays membres-P et FIGAZ; Ph. Degavre, BIML.

Points principaux

Un projet de travail sur les ensembles de mesurage pour gaz combustible avait été préparé par le secrétariat en étroite collaboration avec la Fédération belge des distributeurs de gaz et avait été distribué en avril 1996. L'objectif principal de cette réunion était de discuter des principes de ce projet, en particulier des points suivants:

- Domaine d'application et structure du projet (celui-ci constitue-t-il une bonne base pour les futurs travaux?)
- Définitions
- Débit maximal du système de mesurage ($Q_{max} \geq 100$ m^3/h)

- Exigences et procédures d'essai pour les dispositifs électroniques de conversion de volume de gaz qui devraient figurer dans le projet. Il est souhaitable que celles-ci soient conformes aux exigences et procédures d'essai du projet développé par CEN/TC 237/WG 4.

- Systèmes distributeurs routiers. Ceux-ci doivent être considérés dans un chapitre séparé du projet. Des exigences appropriées seront développées par le secrétariat en même temps que des procédures d'essai.

- Erreurs maximales tolérées. Le secretariat a proposé un Tableau préliminaire divisé en 3 classes d'exactitude A, B et C, qui donne les EMT pour les mesurages de température, pression, masse volumique, pouvoir calorifique, facteur de compressibilité et volume.

- Cohérence de ce projet avec d'autres Recommandations, Normes (ISO, CEN) et liaisons à établir en vue d'une future coopération sur ce projet.

La prochaine réunion du TC 8/SC 7 est prévue les 10–12 mars 1997 à Bruxelles. ■

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Fuel gas metering - an overview

The objective of the working document drafted by OIML TC 8/SC 7 is to set out the metrological and technical requirements applicable to dynamic measurement systems of gas quantities which are subject to legal metrological control.

Systems concerned, which can be located either within one country or at the border between two countries, are those with a minimum nominal capacity equal to or greater than 100 m³/h at base conditions and for operating pressures equal to or greater than 2 bar.

They can be used for custody measurements or for measurements made within the scope of international gas transit.

The metrological components of each measuring system must meet the requirements of specific Recommendations (OIML R 6, R 32, etc.).

Participants at the meeting (left to right):
Top: R. Eggermont, Ph. Degavre, Y. Lemaire
Bottom: G. Wendt, M. Kachút, B. Lind-Nielsen, J. G. Tuinder

Mesurage du gaz combustible - une approche globale

L'objectif du document de travail préparé par OIML TC 8/SC 7 est de fixer les exigences métrologiques et techniques qui s'appliquent aux ensembles de mesurage dynamique des quantités de gaz, soumis au contrôle métrologique légal.

Les ensembles concernés, qui peuvent être localisés soit à l'intérieur d'un pays soit à la frontière entre deux pays, sont ceux ayant une capacité nominale minimale supérieure ou égale à 100m³/h dans les conditions de base et pour des pressions de fonctionnement supérieure ou égale à 2 bar.

Ceux-ci peuvent être utilisés à des fins domestiques ou dans le cadre du commerce international du gaz.

Les éléments métrologiques de chaque ensemble de mesurage doivent respecter les exigences des Recommendations spécifiques (OIML R 6, R 32, etc.).

REGISTERED OIML CERTIFICATES – *CERTIFICATS OIML ENREGISTRÉS*

1996.06 – 1996.08

This list is classified by issuing authority; updated information on these authorities may be obtained from BIML.

Cette liste est classée par autorité de délivrance; les informations à jour relatives à ces autorités sont disponibles auprès du BIML.

Issuing authority / *Autorité de délivrance*

Physikalisch-Technische Bundesanstalt (PTB), Germany

R 76/1992 - DE - 93.01
Sartorius AG
Weender Landstraße 94-108, D-37075 Göttingen, Germany
BA BA 200, BA BB 200, ...

For each Member State, certificates are numbered in the order of their issue (renumbered annually).

Pour chaque Etat Membre, les certificats sont numérotés par ordre de délivrance (cette numérotation est annuelle).

OIML Recommendation applicable within the System / Year of publication

Recommandation OIML applicable dans le cadre du Système / Année d'édition

Year of issue
Année de délivrance

The code (ISO) of the Member State in which the certificate was issued.

Le code (ISO) indicatif de l'Etat Membre ayant délivré le certificat.

Manufacturer / *Fabricant*
Certified pattern(s) / *Modèle(s) certifié(s)*

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Load cells
Cellules de pesée

R 60 (1991), Annex A (1993)

Issuing Authority / Autorité de délivrance

Danish Agency for Development of Trade and Industry, Denmark

R60/1991-DK-96.01
Veccer Ltd., 5 Trafford Road, Reading, Berkshire RG1 8JP, Great Britain

Shear beam load cell type KOE 4200 (Class C)

R60/1991-DK-96.02
Veccer Ltd., 5 Trafford Road, Reading, Berkshire RG1 8JP, Great Britain

Shear beam load cell type KOE 2000S (Class C)

R60/1991-DK-96.03
Veccer Ltd., 5 Trafford Road, Reading, Berkshire RG1 8JP, Great Britain

Shear beam load cell type KOE 8600 (Class C)

Issuing Authority / Autorité de délivrance

Netherlands Measurement Institute (NMi) IJkwezen B.V., The Netherlands

R60/1991-NL-96.03
Tedea Huntleigh International Ltd., 60 Medinat Hayehudim, Herzliya 46120, Israel

1022, P_i = 0.7, maximum capacity up to 20 kg (Classes C and D)

R60/1991-NL-96.04
Epel Industrial S.A., Ctra. Sta. Cruz de Calafell, 35 km. 9,400, 08830 Sant Boi de Llobregat, Barcelona, Spain
BP, P_i = 0.7 (Class C)

R60/1991-NL-96.05
Tedea Huntleigh International Ltd., 60 Medinat Hayehudim, Herzliya 46120, Israël
1022, P_i = 0.7, maximum capacity up to 35 kg (Classes C and D)

INSTRUMENT CATEGORY
CATÉGORIE D'INSTRUMENT

Nonautomatic weighing instruments
Instruments de pesage à fonctionnement non automatique

R 76-1 (1992), R 76-2 (1993)

- **Issuing Authority / Autorité de délivrance**

  National Weights and Measures Laboratory (NWML), United Kingdom

R76/1992-GB-96.01
Western Scale Co. Ltd., 1670 Kingsway Avenue, Port Coquitlam, British Columbia, Canada V3C 3Y9
Weighing Instrument DF 2500 (Classes III and IIII)

- **Issuing Authority / Autorité de délivrance**

  Netherlands Measurement Institute (NMi) IJkwezen B.V., The Netherlands

R76/1992-NL-96.02
Teraoka Seiko Co., Ltd., 12-13 Kugahara, 5-Chome, Otha-ku, Tokyo 146, Japan
DS-73x, 6 kg ≤ Max ≤ 30 kg, multi-interval with a maximum of two intervals, n ≤ 3000 (per interval) (Class III)

R76/1992-NL-96.03
Teraoka Seiko Co., Ltd., 12-13 Kugahara, 5-Chome, Otha-ku, Tokyo 146, Japan
DS-690, 30 kg ≤ Max ≤ 600 kg, n ≤ 3000 divisions (Class III)

R76/1992-NL-96.04
Mettler-Toledo A.G., Im Langacher, 8606 Greifensee, Switzerland
HR.. and HG Moisture Analyzer, Max ≤ 71 g, n ≤ 71 000, e ≥ 1 mg, e = d or e = 10 d (Class I)

R76/1992-NL-96.05
Yamato Scale Co., Ltd., 5-22 Saenba-cho, Akashi 673, Japan
TDW, Max ≤ 15 kg, e ≥ 1 g, n ≤ 3000 divisions (Class III)

R76/1992-NL-96.06
Mettler-Toledo Inc., 1150 Dearborn Drive, Worthington, OH 43085-6712, USA
*TW***, 3 kg ≤ Max ≤ 60 kg, n ≤ 3000 (Class III)*

R76/1992-NL-96.07
Teraoka Seiko Co., Ltd., 12-13 Kugahara, 5-Chome, Otha-ku, Tokyo 146, Japan
FX-3600 (XL), n ≤ 3000 (per partial weighing range), 6 kg ≤ Max ≤ 15 kg, maximum of two partial weighing ranges (Class III)

R76/1992-NL-96.08
Ishida Co., Ltd., 44, Sanno-cho, Shogoin, Sakayo-ku, Kyoto 606, Japan
MTX series, 15 kg ≤ Max ≤ 150 kg, e ≥ 5 g, n ≤ 3000 divisions (per weighing range), maximum of two weighing ranges (Class I)

R76/1992-NL-96.11
Baster Ltd., Organize Sanayi, 10000 Sokak No. 19, 35620 Çiğli / Izmir, Turkey
EP-15, Max = 15 kg, n ≤ 3000 (Class III)

R76/1992-NL-96.12
Tokyo Electric Co., Ltd., 6-78, Minami-cho, Mishima-shi, Shizuoka-ken 411, Japan
SL 9000, n ≤ 3200 divisions (per partial weighing range, with a maximum of two weighing ranges), Max ≤ 15 kg or Max ≤ 25 lb, e ≥ 2 g or e ≥ 1/8 oz (Class III)

NEW PUBLICATIONS
NOUVELLES PUBLICATIONS

R 51-2 (F)	Instruments de pesage trieurs-étiqueteurs à fonctionnement automatique. Partie 2: Format du rapport d'essai
D 25	Vortex meters used in measuring systems for fluids *Compteurs à vortex utilisés dans les ensembles de mesurage de fluides*

Available in French and English (see OIML Bulletin supplement for price-list). To order a publication, please contact OIML headquarters:
Bureau International de Métrologie Légale 11, rue Turgot - 75009 Paris - France Fax: 33 (0)1 42 82 17 27

Métrologie et santé

La France se dote d'un accélérateur linéaire étalon

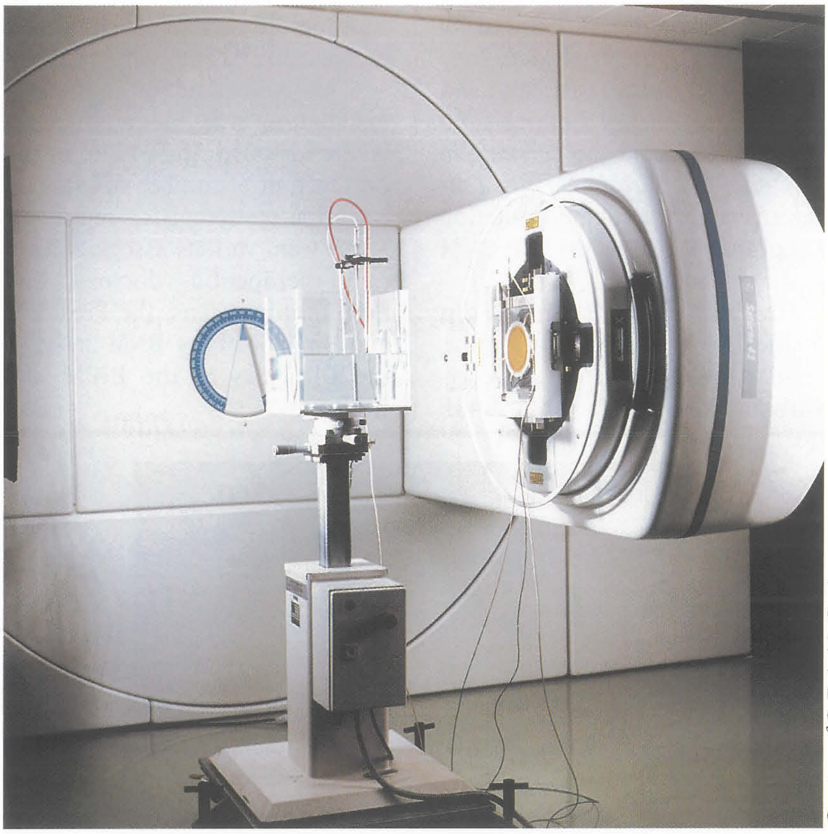
L'utilisation des accélérateurs linéaires en radiothérapie a connu ces dernières années, et dans beaucoup de pays, un développement rapide en raison des avantages que présentent ces appareils par rapport aux anciennes installations de radiothérapie, en particulier en ce qui concerne la gamme d'énergie disponible. En France ce sont maintenant plus de 200 appareils de ce type qui sont utilisés dans les hôpitaux pour le traitement des cancers.

Néanmoins un problème crucial se pose: celui de leur étalonnage dans toute leur gamme d'énergie. Les radiothérapeutes-oncologues et les physiciens d'hôpital estiment en effet que, compte tenu de toutes les sources d'imprécisions qui existent par ailleurs, les doses de rayonnement doivent être connues à mieux que 2 % si l'on veut que la thérapie soit efficace. Or les étalons de dosimétrie classiques ne permettent pas de couvrir la gamme d'énergie des accélérateurs linéaires.

À l'image de quelques rares autres pays (Allemagne, Royaume-Uni, USA), la France vient de se doter d'un accélérateur linéaire étalon, cofinancé par le Bureau National de Métrologie (BNM), le Ministère de la Santé, et le Commissariat à l'Énergie Atomique (CEA), qui héberge le Laboratoire Primaire des Rayonnements Ionisant (LPRI), l'un des cinq laboratoires primaires du BNM.

L'étalon est en fait un accélérateur linéaire de type médical, semblable aux nombreux appareils utilisés en France (Saturne 43 F de GEMS), mais qui a été spécialement adapté à une activité d'étalonnage. Il a en particulier été débarrassé de tous les dispositifs nécessaires à une utilisation purement médicale, et au contraire sa gamme de fonctionnement a été considérablement élargie par rapport aux appareils médicaux: il peut en effet procurer 8 énergies d'électrons, de 4 à 21 MeV, et 9 énergies de photons X, de 4 à 25 MeV; par ailleurs, les débits de dose peuvent varier entre 30 et 200 Gy/h.

L'inauguration de cette installation étalon a été faite le mercredi 3 avril 1996, en présence de nombreux spécialistes de la métrologie des rayonnements ionisants, de représentants des associations de médecins radiothérapeutes et des physiciens d'hôpital, du Président et du Directeur du BNM, ainsi que des Directeurs du BIPM et du BIML. B.A.



Courtesy of C. E. A. / A. Gonin

Accélérateur Delphes - Delphes Accelerator

Metrology for health

France is now equipped with a standard linear accelerator

Over the past few years, the use of linear accelerators in the field of radiotherapy has increased significantly in many countries. This is due to the many advantages that this type of equipment offers compared to older radiotherapy installations, especially regarding the wider range of energies now available. In France today, over 200 devices of this type are being used in hospitals for the treatment of cancer.

Nevertheless, a crucial problem must be addressed, namely their calibration within their total energy range. In fact radiotherapic oncologists and hospital physicians consider that, in view of the various possible sources of inaccuracy which exist, radiation doses should be ascertained to within 2 % if the therapy is to be effective. However, classic dosimetry standards do not sufficiently cover the energy ranges of linear accelerators.

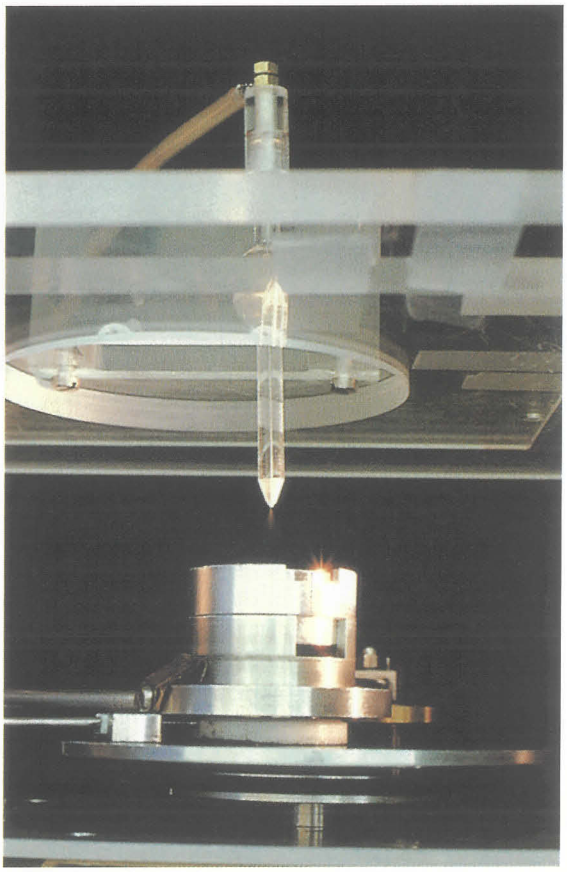
Following the example of a limited number of other countries such as Germany, the United Kingdom and the USA, France has just equipped itself with a standard linear accelerator, co-financed by the National Bureau of Metrology (BNM), the Ministry of Health and the Atomic Energy Commission. The latter harbors the *Laboratoire Primaire des Rayonnements Ionisant* (Primary Ionizing Radiation Laboratory), one of the five BNM primary laboratories.

In fact this standard is a medical type linear accelerator, similar to numerous devices currently used in France (Saturn 43F from GEMS), but which has been specially adapted for calibration purposes.

All the accouterments which were solely of use in the medical field have been removed - indeed its functional domain has been considerably enlarged compared to purely medical-oriented equipments: it can produce 8 levels of electron energies in the range of 4 to 21 MeV and 9 X-photon energies from 4 to 25 MeV. In addition, dose rates can be varied between 30 and 200 Gy/h.

This new standard equipment installation was inaugurated on Wednesday 3rd April 1996, in the presence of a number of ionizing radiation metrologists, representatives from various associations of radio-therapeutic doctors and hospital physicians, the President and Director of the BNM and also the Directors of the BIPM and BIML.

B.A.



Preparation of standard primary source of activity (BNM-LPRI)

Ionizing radiations

The BNM assigned the task of elaborating and improving national primary reference measurements for radioactivity and ionizing radiation to the Laboratoire Primaire des Rayonnements Ionisant.

The BNM-LPRI has the responsibility for implementing ionizing radiation metrology standards in various fields: hospitals, industry, national defence and R&D laboratories.

Due to the different kinds of radiations and radioactive sources in existence, the BNM-LPRI has developed a large range of measurement methods and techniques.

To characterize reference radiation beams in dosimetry, measurement methods are based on calorimeters, ionizing chambers and chemical dosimeters.

Vient de paraître:

▶ ETALONS ET UNITES DE MESURE

Les bases de la métrologie en France: mise en pratique du Système international d'unités.

Ce livre a été rédigé par les ingénieurs au secrétariat permanent du Bureau National de Métrologie, avec la participation des Laboratoires nationaux de métrologie du BNM.

Aujourd'hui, la mesure est une composante permanente de notre environnement, de notre formation et de la vie de nos entreprises.

Or, toute prise de décision à partir d'une mesure nécessite une bonne interprétation de cette mesure. Il faut notamment connaître le système de référence et l'incertitude associés à la mesure.

En décidant de publier cet ouvrage, le Bureau National de Métrologie (BNM) a donc souhaité constituer *le document* sur lequel peut s'appuyer toute personne de l'industrie, de l'enseignement ou de la recherche, confrontée aux problèmes de la mesure.

Cet ouvrage est consacré aux définitions des unités de base et des unités dérivées du Système international d'unités (SI), et à la réalisation de l'instrumentation spécifique nécessaire pour la matérialisation de ces unités. Cette instrumentation de très haute technicité est fondée sur des principes physiques multiples.

Il présente également les références nationales: les étalons nationaux de mesure.

▶ **Langue:** Français

▶ **Coût:** 80 Frs T.T.C.

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meetings
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réunions

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2–4	OIML workshop: Practical test procedures for classes E_1 to M_3 weights	BORÅS, SWEDEN
28–30	TC 7/SC 5 Dimensional measuring instruments	GAITHERSBURG, U.S.A.

November 1996

4–8	Tenth International Conference of Legal Metrology	VANCOUVER, CANADA
	31st CIML meeting	
	Development Council meeting	
7	Round table "Accreditation in legal metrology"	

January 1997

20–22	TC 17/SC 7 Breath testers	PARIS, FRANCE

March 1997

10–12	TC 8/SC 7 Gas metering	BRUSSELS, BELGIUM

October 1997

10	TC 13 Measuring instruments for acoustics and vibration	JAPAN

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PUBLICATIONS

classified by subject and number

International Recommendations
International Documents
Other publications

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General
Généralités

R 34 (1979-*1974*) 60 FRF
Accuracy classes of measuring instruments
Classes de précision des instruments de mesurage

R 42 (1981-*1977*) 50 FRF
Metal stamps for verification officers
Poinçons de métal pour Agents de vérification

D 1 (1975) 50 FRF
Law on metrology
Loi de métrologie

D 2 (in revision - *en cours de révision)*
Legal units of measurement
Unités de mesure légales

D 3 (1979) 60 FRF
Legal qualification of measuring instruments
Qualification légale des instruments de mesurage

D 5 (1982) 60 FRF
Principles for the establishment of hierarchy schemes for measuring instruments
Principes pour l'établissement des schémas de hiérarchie des instruments de mesure

D 9 (1984) 60 FRF
Principles of metrological supervision
Principes de la surveillance métrologique

D 12 (1986) 50 FRF
Fields of use of measuring instruments subject to verification
Domaines d'utilisation des instruments de mesure assujettis à la vérification

D 13 (1986) 50 FRF
Guidelines for bi- or multilateral arrangements on the recognition of: test results - pattern approvals - verifications
Conseils pour les arrangements bi- ou multilatéraux de reconnaissance des: résultats d'essais - approbations de modèles - vérifications

D 14 (1989) 60 FRF
Training of legal metrology personnel - Qualification - Training programmes
Formation du personnel en métrologie légale - Qualification - Programmes d'étude

D 15 (1986) 80 FRF
Principles of selection of characteristics for the examination of measuring instruments
Principes du choix des caractéristiques pour l'examen des instruments de mesure usuels

D 16 (1986) 80 FRF
Principles of assurance of metrological control
Principes d'assurance du contrôle métrologique

D 19 (1988) 80 FRF
Pattern evaluation and pattern approval
Essai de modèle et approbation de modèle

D 20 (1988) 80 FRF
Initial and subsequent verification of measuring instruments and processes
Vérifications primitive et ultérieure des instruments et processus de mesure

V 1 (1978) 100 FRF
Vocabulary of legal metrology (bilingual French-English)
Vocabulaire de métrologie légale (bilingue français-anglais)

V 2 (1993) 200 FRF
International vocabulary of basic and general terms in metrology (bilingual French-English)
Vocabulaire international des termes fondamentaux et généraux de métrologie (bilingue français- anglais)

P 1 (1991) 60 FRF
OIML Certificate System for Measuring Instruments
Système de Certificats OIML pour les Instruments de Mesure

P 2 (1987) 100 FRF
Metrology training - Synthesis and bibliography (bilingual French-English)
Formation en métrologie - Synthèse et bibliographie (bilingue français-anglais)

P 3 (1996) 400 FRF
Legal metrology in OIML Member States
Métrologie légale dans les Etats Membres de l'OIML

P 9 (1992) 100 FRF
Guidelines for the establishment of simplified metrology regulations

P 17 (1995) 300 FRF
Guide to the expression of uncertainty in measurement
Guide pour l'expression de l'incertitude de mesure

Measurement standards and verification equipment
Étalons et équipement de vérification

D 6 (1983) 60 FRF
Documentation for measurement standards and calibration devices
Documentation pour les étalons et les dispositifs d'étalonnage

D 8 (1984) 60 FRF
Principles concerning choice, official recognition, use and conservation of measurement standards
Principes concernant le choix, la reconnaissance officielle, l'utilisation et la conservation des étalons

D 10 (1984) 50 FRF
Guidelines for the determination of recalibration intervals of measuring equipment used in testing laboratories
Conseils pour la détermination des intervalles de réétalonnage des équipements de mesure utilisés dans les laboratoires d'essais

D 18 (1987) 50 FRF
General principles of the use of certified reference materials in measurements
Principes généraux d'utilisation des matériaux de référence certifiés dans les mesurages

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Principles of metrological control of equipment used for verification
Principes du contrôle métrologique des équipements utilisés pour la vérification

P 4 (1986–*1981*) 100 FRF
Verification equipment for National Metrology Services
Equipement d'un Service national de métrologie

P 6 (1987) 100 FRF
Suppliers of verification equipment (bilingual French-English)
Fournisseurs d'équipement de vérification (bilingue français-anglais)

P 7 (1989) 100 FRF
Planning of metrology and testing laboratories
Planification de laboratoires de métrologie et d'essais

P 15 (1989) 100 FRF
Guide to calibration

Mass and density
Masses et masses volumiques

R 15 (1974–*1970*) 80 FRF
Instruments for measuring the hectolitre mass of cereals
Instruments de mesure de la masse à l'hectolitre des céréales

R 22 (1975) 150 FRF
International alcoholometric tables (trilingual French-English-Spanish version)
Tables alcoométriques internationales (version trilingue français-anglais-espagnol)

R 33 (1979–*1973*) 50 FRF
Conventional value of the result of weighing in air
Valeur conventionnelle du résultat des pesées dans l'air

R 44 (1985) 50 FRF
Alcoholometers and alcohol hydrometers and thermometers for use in alcoholometry
Alcoomètres et aréomètres pour alcool et thermomètres utilisés en alcoométrie

R 47 (1979–*1978*) 60 FRF
Standard weights for testing of high capacity weighing machines
Poids étalons pour le contrôle des instruments de pesage de portée élevée

R 50 (1994) 100 FRF
Continuous totalizing automatic weighing instruments
Instruments de pesage totalisateurs continus à fonctionnement automatique

R 51-1 (1996) 100 FRF
Automatic catchweighing instruments. Part 1: Metrological and technical requirements - Tests
Instruments de pesage trieurs-étiqueteurs à fonctionnement automatique. Partie 1: Exigences métrologiques et techniques - Essais

R 51-2 (1996) 300 FRF
Automatic catchweighing instruments. Part 2: Test report format
Instruments de pesage trieurs-étiqueteurs à fonctionnement automatique. Partie 2: Format du rapport d'essai

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Hexagonal weights, ordinary accuracy class from 100 g to 50 kg
Poids hexagonaux de classe de précision ordinaire, de 100 g à 50 kg

R 60 (1991) 80 FRF
Metrological regulation for load cells
Réglementation métrologique des cellules de pesée

Annex (1993) 80 FRF
Test report format for the evaluation of load cells
Format du rapport d'essai des cellules de pesée

R 61 (being printed - *en cours de publication*)
Automatic gravimetric filling instruments
Doseuses pondérales à fonctionnement automatique

R 74 (1993) 80 FRF
Electronic weighing instruments
Instruments de pesage électroniques

R 76-1 (1992) 300 FRF
Nonautomatic weighing instruments Part 1: Metrological and technical requirements - Tests
Instruments de pesage à fonctionnement non automatique Partie 1: Exigences métrologiques et techniques - Essais

Amendment No. 1 (1994) free / *gratuit*

R 76-2 (1993) 200 FRF
Nonautomatic weighing instruments Part 2: Pattern evaluation report
Instruments de pesage à fonctionnement non automatique Partie 2: Rapport d'essai de modèle

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R 106 (1993) 100 FRF
Automatic rail-weighbridges
Ponts-bascules ferroviaires à fonctionnement automatique

Annex (being printed - *en cours de publication*)
Test procedures and test report format
Procédures d'essai et format du rapport d'essai

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Discontinuous totalizing automatic weighing instruments (totalizing hopper weighers)
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Poids des classes E_1, E_2, F_1, F_2, M_1, M_2, M_3

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Speedometers, mechanical odometers and chronotachographs for motor vehicles. Metrological regulations
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Length measuring instruments
Instruments mesureurs de longueurs

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Radar equipment for the measurement of the speed of vehicles
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Tables de mesure du pétrole

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Réservoirs de stockage fixes. Prescriptions générales

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Measuring devices and measuring systems for cryogenic liquids (including tables of density for liquid argon, helium, hydrogen, nitrogen and oxygen)
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Ensembles de mesurage massiques directs de quantités de liquides

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R 23 (1975-1973) 60 FRF
Tyre pressure gauges for motor vehicles
Manomètres pour pneumatiques de véhicules automobiles

(*) See also "Liquid measurement" D 25 – *Voir aussi "Mesurage des liquides" D 25.*

(**) See also "Medical instruments" - *Voir aussi "Instruments médicaux".*

R 53 (1982) 60 FRF
Metrological characteristics of elastic sensing elements used for measurement of pressure. Determination methods
Caractéristiques métrologiques des éléments récepteurs élastiques utilisés pour le mesurage de la pression. Méthodes de leur détermination

R 97 (1990) 60 FRF
Barometers
Baromètres

R 101 (1991) 80 FRF
Indicating and recording pressure gauges, vacuum gauges and pressure vacuum gauges with elastic sensing elements (ordinary instruments)
Manomètres, vacuomètres et manovacuomètres indicateurs et enregistreurs à élément récepteur élastique (instruments usuels)

R 109 (1993) 60 FRF
Pressure gauges and vacuum gauges with elastic sensing elements (standard instruments)
Manomètres et vacuomètres à élément récepteur élastique (instruments étalons)

R 110 (1994) 80 FRF
Pressure balances
Manomètres à piston

Temperature
Températures(*)

R 18 (1989) 60 FRF
Visual disappearing filament pyrometers
Pyromètres optiques à filament disparaissant

R 48 (1980-*1978*) 50 FRF
Tungsten ribbon lamps for calibration of optical pyrometers
Lampes à ruban de tungstène pour l'étalonnage des pyromètres optiques

R 75 (1988) 60 FRF
Heat meters
Compteurs d'énergie thermique

R 84 (1989) 60 FRF
Resistance-thermometer sensors made of platinum, copper or nickel (for industrial and commercial use)
Capteurs à résistance thermométrique de platine, de cuivre ou de nickel (à usages techniques et commerciaux)

D 24 (1996) 60 FRF
Total radiation pyrometers
Pyromètres à radiation totale

P 16 (1991) 100 FRF
Guide to practical temperature measurements

(*) See also "Medical instruments" - *Voir aussi "Instruments médicaux".*

Electricity
Électricité

R 46 (1980-*1978*) 80 FRF
Active electrical energy meters for direct connection of class 2
Compteurs d'énergie électrique active à branchement direct de la classe 2

D 11 (1994) 80 FRF
General requirements for electronic measuring instruments
Exigences générales pour les instruments de mesure électroniques

Acoustics and vibration
Accoustique et vibrations(*)

R 58 (in revision - *en cours de révision)*
Sound level meters
Sonomètres

R 88 (in revision - *en cours de révision)*
Integrating-averaging sound level meters
Sonomètres intégrateurs-moyenneurs

R 102 (1992) 50 FRF
Sound calibrators
Calibreurs acoustiques

Annex (1995) 80 FRF
Test methods for pattern evaluation and test report format
Méthodes d'essai de modèle et format du rapport d'essai

R 103 (1992) 60 FRF
Measuring instrumentation for human response to vibration
Appareillage de mesure pour la réponse des individus aux vibrations

R 104 (1993) 60 FRF
Pure-tone audiometers
Audiomètres à sons purs

Annex (being printed - *en cours de publication*)
Test report format
Format du rapport d'essai

Environment
Environnement

R 82 (1989) 80 FRF
Gas chromatographs for measuring pollution from pesticides and other toxic substances
Chromatographes en phase gazeuse pour la mesure des pollutions par pesticides et autres substances toxiques

R 83 (1990) 80 FRF
Gas chromatograph/mass spectrometer/data system for analysis of organic pollutants in water
Chromatographe en phase gazeuse équipé d'un spectromètre de masse et d'un système de traitement de données pour l'analyse des polluants organiques dans l'eau

R 99 (1991) 100 FRF
Instruments for measuring vehicle exhaust emissions
Instruments de mesure des gaz d'échappement des véhicules

R 100 (1991) 80 FRF

Atomic absorption spectrometers for measuring metal pollutants in water
Spectromètres d'absorption atomique pour la mesure des polluants métalliques dans l'eau

R 112 (1994) 80 FRF

High performance liquid chromatographs for measurement of pesticides and other toxic substances
Chromatographes en phase liquide de haute performance pour la mesure des pesticides et autres substances toxiques

R 113 (1994) 80 FRF

Portable gas chromatographs for field measurements of hazardous chemical pollutants
Chromatographes en phase gazeuse portatifs pour la mesure sur site des polluants chimiques dangereux

R 116 (1995) 80 FRF

Inductively coupled plasma atomic emission spectrometers for measurement of metal pollutants in water
Spectromètres à émission atomique de plasma couplé inductivement pour le mesurage des polluants métalliques dans l'eau

R 123 (being printed - *en cours de publication*)

Portable and transportable X-ray fluorescence spectrometers for field measurement of hazardous elemental pollutants
Spectromètres à fluorescence de rayons X portatifs et déplaçables pour la mesure sur le terrain d'éléments polluants dangereux

D 22 (1991) 80 FRF

Guide to portable instruments for assessing airborne pollutants arising from hazardous wastes
Guide sur les instruments portatifs pour l'évaluation des polluants contenus dans l'air en provenance des sites de décharge de déchets dangereux

Physico-chemical measurements
Mesures physico-chimiques

R 14 (1995) 60 FRF

Polarimetric saccharimeters
Saccharimètres polarimétriques

R 54 (in revision - *en cours de révision*)

pH scale for aqueous solutions
Echelle de pH des solutions aqueuses

R 56 (1981) 50 FRF

Standard solutions reproducing the conductivity of electrolytes
Solutions-étalons reproduisant la conductivité des électrolytes

R 59 (1984) 80 FRF

Moisture meters for cereal grains and oilseeds
Humidimètres pour grains de céréales et graines oléagineuses

R 68 (1985) 50 FRF

Calibration method for conductivity cells
Méthode d'étalonnage des cellules de conductivité

R 69 (1985) 50 FRF

Glass capillary viscometers for the measurement of kinematic viscosity. Verification method
Viscosimètres à capillaire, en verre, pour la mesure de la viscosité cinématique. Méthode de vérification

R 70 (1985) 50 FRF

Determination of intrinsic and hysteresis errors of gas analysers
Détermination des erreurs de base et d'hystérésis des analyseurs de gaz

R 73 (1985) 50 FRF

Requirements concerning pure gases CO, CO_2, CH_4, H_2, O_2, N_2 and Ar intended for the preparation of reference gas mixtures
Prescriptions pour les gaz purs CO, CO_2, CH_4, H_2, O_2, N_2 et Ar destinés à la préparation des mélanges de gaz de référence

R 92 (1989) 60 FRF

Wood-moisture meters - Verification methods and equipment: general provisions
Humidimètres pour le bois - Méthodes et moyens de vérification: exigences générales

R 108 (1993) 60 FRF

Refractometers for the measurement of the sugar content of fruit juices
Réfractomètres pour la mesure de la teneur en sucre des jus de fruits

R 121 (1996) 60 FRF

The scale of relative humidity of air certified against satured salt solutions
Échelle d'humidité relative de l'air certifiée par rapport à des solutions saturées de sels

D 17 (1987) 50 FRF

Hierarchy scheme for instruments measuring the viscosity of liquids
Schéma de hiérarchie des instruments de mesure de la viscosité des liquides

Medical instruments
Instruments médicaux

R 7 (1979–*1978*) 60 FRF

Clinical thermometers, mercury-in-glass with maximum device
Thermomètres médicaux à mercure, en verre, avec dispositif à maximum

R 16 (1973–*1970*) 50 FRF

Manometers for instruments for measuring blood pressure (sphygmomanometers)
Manomètres des instruments de mesure de la tension artérielle (sphygmomanomètres)

R 26 (1978–*1973*) 50 FRF

Medical syringes
Seringues médicales

R 78 (1989) 50 FRF

Westergren tubes for measurement of erythrocyte sedimentation rate
Pipettes Westergren pour la mesure de la vitesse de sédimentation des hématies

R 89 (1990) 80 FRF

Electroencephalographs - Metrological characteristics - Methods and equipment for verification
Electroencéphalographes - Caractéristiques métrologiques - Méthodes et moyens de vérification

R 90 (1990) 80 FRF

Electrocardiographs - Metrological characteristics - Methods and equipment for verification
Electrocardiographes - Caractéristiques métrologiques - Méthodes et moyens de vérification

R 93 (1990) 60 FRF

Focimeters
Frontofocomètres

R 114 (1995) 80 FRF

Clinical electrical thermometers for continuous measurement
Thermomètres électriques médicaux pour mesurage en continu

R 115 (1995) 80 FRF

Clinical electrical thermometers with maximum device
Thermomètres électriques médicaux avec dispositif à maximum

R 122 (1996) 60 FRF

Equipment for speech audiometry
Appareils pour l'audiométrie vocale

D 21 (1990) 80 FRF

Secondary standard dosimetry laboratories for the calibration of dosimeters used in radiotherapy
Laboratoires secondaires d'étalonnage en dosimétrie pour l'étalonnage des dosimètres utilisés en radiothérapie

Testing of materials
Essais des matériaux

R 9 (1972-*1970*) 60 FRF

Verification and calibration of Brinell hardness standardized blocks
Vérification et étalonnage des blocs de référence de dureté Brinell

R 10 (1974-*1970*) 60 FRF

Verification and calibration of Vickers hardness standardized blocks
Vérification et étalonnage des blocs de référence de dureté Vickers

R 11 (1974-*1970*) 60 FRF

Verification and calibration of Rockwell B hardness standardized blocks
Vérification et étalonnage des blocs de référence de dureté Rockwell B

R 12 (1974-*1970*) 60 FRF

Verification and calibration of Rockwell C hardness standardized blocks
Vérification et étalonnage des blocs de référence de dureté Rockwell C

R 36 (1980-*1977*) 60 FRF

Verification of indenters for hardness testing machines
Vérification des pénétrateurs des machines d'essai de dureté

R 37 (1981-*1977*) 60 FRF

Verification of hardness testing machines (Brinell system)
Vérification des machines d'essai de dureté (système Brinell)

R 38 (1981-*1977*) 60 FRF

Verification of hardness testing machines (Vickers system)
Vérification des machines d'essai de dureté (système Vickers)

R 39 (1981-*1977*) 60 FRF

Verification of hardness testing machines (Rockwell systems B,F,T - C,A,N)
Vérification des machines d'essai de dureté (systèmes Rockwell B,F,T -C,A,N)

R 62 (1985) 80 FRF

Performance characteristics of metallic resistance strain gauges
Caractéristiques de performance des extensomètres métalliques à résistance

R 64 (1985) 50 FRF

General requirements for materials testing machines
Exigences générales pour les machines d'essai des matériaux

R 65 (1985) 60 FRF

Requirements for machines for tension and compression testing of materials
Exigences pour les machines d'essai des matériaux en traction et en compression

V 3 (1991) 80 FRF

Hardness testing dictionary (quadrilingual French-English-German-Russian)
Dictionnaire des essais de dureté (quadrilingue français-anglais-allemand-russe)

P 10 (1981) 50 FRF

The metrology of hardness scales - Bibliography

P 11 (1983) 100 FRF

Factors influencing hardness measurement

P 12 (1984) 100 FRF

Hardness test blocks and indenters

P 13 (1989) 100 FRF

Hardness standard equipment

P 14 (1991) 100 FRF

The unification of hardness measurement

Prepackaging
Préemballages

R 79 (in revision - *en cours de révision)*

Information on package labels
Etiquetage des préemballages

R 87 (1989) 50 FRF

Net content in packages
Contenu net des préemballages

INTERNATIONAL RECOMMENDATIONS
RECOMMANDATIONS INTERNATIONALES

R 4 (1970-1972) 50 FRF
Volumetric flasks (one mark) in glass
Fioles jaugées à un trait en verre

R 6 (1989) 80 FRF
General provisions for gas volume meters
Dispositions générales pour les compteurs de volume de gaz

R 7 (1979-1978) 60 FRF
Clinical thermometers, mercury-in-glass with maximum device
Thermomètres médicaux à mercure, en verre, avec dispositif à maximum

R 9 (1972-1970) 60 FRF
Verification and calibration of Brinell hardness standardized blocks
Vérification et étalonnage des blocs de référence de dureté Brinell

R 10 (1974-1970) 60 FRF
Verification and calibration of Vickers hardness standardized blocks
Vérification et étalonnage des blocs de référence de dureté Vickers

R 11 (1974-1970) 60 FRF
Verification and calibration of Rockwell B hardness standardized blocks
Vérification et étalonnage des blocs de référence de dureté Rockwell B

R 12 (1974-1970) 60 FRF
Verification and calibration of Rockwell C hardness standardized blocks
Vérification et étalonnage des blocs de référence de dureté Rockwell C

R 14 (1995) 60 FRF
Polarimetric saccharimeters
Saccharimètres polarimétriques

R 15 (1974-1970) 80 FRF
Instruments for measuring the hectolitre mass of cereals
Instruments de mesure de la masse à l'hectolitre des céréales

R 16 (1973-1970) 50 FRF
Manometers for instruments for measuring blood pressure (sphygmomanometers)
Manomètres des instruments de mesure de la tension artérielle (sphygmomanomètres)

R 18 (1989) 60 FRF
Visual disappearing filament pyrometers
Pyromètres optiques à filament disparaissant

R 21 (1975-1973) 60 FRF
Taximeters
Taximètres

R 22 (1975-1973) 150 FRF
International alcoholometric tables (trilingual French-English-Spanish)
Tables alcoométriques internationales (trilingue français-anglais-espagnol)

R 23 (1975-1973) 60 FRF
Tyre pressure gauges for motor vehicles
Manomètres pour pneumatiques de véhicules automobiles

R 24 (1975-1973) 50 FRF
Standard one metre bar for verification officers
Mètre étalon rigide pour agents de vérification

R 26 (1978-1973) 50 FRF
Medical syringes
Seringues médicales

R 29 (1979-1973) 50 FRF
Capacity serving measures
Mesures de capacité de service

R 30 (1981) 60 FRF
End standards of length (gauge blocks)
Mesures de longueur à bouts plans (cales étalons)

R 31 (1995) 80 FRF
Diaphragm gas meters
Compteurs de gaz à parois déformables

R 32 (1989) 60 FRF
Rotary piston gas meters and turbine gas meters
Compteurs de volume de gaz à pistons rotatifs et compteurs de volume de gaz à turbine

R 33 (1979-1973) 50 FRF
Conventional value of the result of weighing in air
Valeur conventionnelle du résultat des pesées dans l'air

R 34 (1979-1974) 60 FRF
Accuracy classes of measuring instruments
Classes de précision des instruments de mesurage

R 35 (1985) 80 FRF
Material measures of length for general use
Mesures matérialisées de longueur pour usages généraux

R 36 (1980-1977) 60 FRF
Verification of indenters for hardness testing machines
Vérification des pénétrateurs des machines d'essai de dureté

R 37 (1981-1977) 60 FRF
Verification of hardness testing machines (Brinell system)
Vérification des machines d'essai de dureté (système Brinell)

R 38 (1981-1977) 60 FRF
Verification of hardness testing machines (Vickers system)
Vérification des machines d'essai de dureté (système Vickers)

R 39 (1981-1977) 60 FRF
Verification of hardness testing machines (Rockwell systems B,F,T-C,A,N)
Vérification des machines d'essai de dureté (systèmes Rockwell B,F,T-C,A,N)

R 40 (1981-1977) 60 FRF
Standard graduated pipettes for verification officers
Pipettes graduées étalons pour agents de vérification

R 41 (1981-1977) 60 FRF
Standard burettes for verification officers
Burettes étalons pour agents de vérification

R 42 (1981-1977) 50 FRF
Metal stamps for verification officers
Poinçons de métal pour agents de vérification

R 43 (1981-1977) 60 FRF
Standard graduated glass flasks for verification officers
Fioles étalons graduées en verre pour agents de vérification

R 44 (1985) 50 FRF
Alcoholometers and alcohol hydrometers and thermometers for use in alcoholometry
Alcoomètres et aréomètres pour alcool et thermomètres utilisés en alcoométrie

R 45 (1980-1977) 50 FRF
Casks and barrels
Tonneaux et futailles

R 46 (1980-1978) 80 FRF
Active electrical energy meters for direct connection of class 2
Compteurs d'énergie électrique active à branchement direct de la classe 2

R 47 (1979-1978) 60 FRF
Standard weights for testing of high capacity weighing machines
Poids étalons pour le contrôle des instruments de pesage de portée élevée

R 48 (1980-1978) 50 FRF
Tungsten ribbon lamps for calibration of optical pyrometers
Lampes à ruban de tungstène pour l'étalonnage des pyromètres optiques

R 49 (in revision - *en cours de révision*)
Water meters intended for the metering of cold water
Compteurs d'eau destinés au mesurage de l'eau froide

R 50 (1994) 100 FRF
Continuous totalizing automatic weighing instruments (belt weighers)
Instruments de pesage totalisateurs continus à fonctionnement automatique (peseuses sur bande)

R 51-1 (1996) 100 FRF
Automatic catchweighing instruments. Part 1: Metrological and technical requirements - Tests
Instruments de pesage trieurs-étiqueteurs à fonctionnement automatique. Partie 1: Exigences métrologiques et techniques - Essais

R 51-2 (1996) 300 FRF
Automatic catchweighing instruments. Part 2: Test report format
Instruments de pesage trieurs-étiqueteurs à fonctionnement automatique. Partie 2: Format du rapport d'essai

R 52 (1980) 50 FRF
Hexagonal weights, ordinary accuracy class from 100 g to 50 kg
Poids hexagonaux de classe de précision ordinaire, de 100 g à 50 kg

R 53 (1982) 60 FRF
Metrological characteristics of elastic sensing elements used for measurement of pressure. Determination methods
Caractéristiques métrologiques des éléments récepteurs élastiques utilisés pour le mesurage de la pression. Méthodes de leur détermination

R 54 (in revision - *en cours de révision*)
pH scale for aqueous solutions
Echelle de pH des solutions aqueuses

R 55 (1981) 50 FRF
Speedometers, mechanical odometers and chronotachographs for motor vehicles. Metrological regulations
Compteurs de vitesse, compteurs mécaniques de distance et chronotachygraphes des véhicules automobiles. Réglementation métrologique

R 56 (1981) 50 FRF
Standard solutions reproducing the conductivity of electrolytes
Solutions-étalons reproduisant la conductivité des électrolytes

R 58 (in revision - *en cours de révision*)
Sound level meters
Sonomètres

R 59 (1984) 80 FRF
Moisture meters for cereal grains and oilseeds
Humidimètres pour grains de céréales et graines oléagineuses

R 60 (1991) 80 FRF
Metrological regulation for load cells
Réglementation métrologique des cellules de pesée

Annex (1993) 80 FRF
Test report format for the evaluation of load cells
Format du rapport d'essai des cellules de pesée

R 61 (being printed - *en cours de publication*)
Automatic gravimetric filling instruments
Doseuses pondérales à fonctionnement automatique

R 62 (1985) 80 FRF
Performance characteristics of metallic resistance strain gauges
Caractéristiques de performance des extensomètres métalliques à résistance

R 63 (1994) 50 FRF
Petroleum measurement tables
Tables de mesure du pétrole

R 64 (1985) 50 FRF
General requirements for materials testing machines
Exigences générales pour les machines d'essai des matériaux

R 65 (1985) 60 FRF
Requirements for machines for tension and compression testing of materials
Exigences pour les machines d'essai des matériaux en traction et en compression

R 66 (1985) 60 FRF
Length measuring instruments
Instruments mesureurs de longueurs

R 68 (1985) 50 FRF
Calibration method for conductivity cells
Méthode d'étalonnage des cellules de conductivité

R 69 (1985) 50 FRF
Glass capillary viscometers for the measurement of kinematic viscosity. Verification method
Viscosimètres à capillaire, en verre, pour la mesure de la viscosité cinématique. Méthode de vérification

R 70 (1985) 50 FRF
Determination of intrinsic and hysteresis errors of gas analysers
Détermination des erreurs de base et d'hystérésis des analyseurs de gaz

R 71 (1985) 80 FRF
Fixed storage tanks. General requirements
Réservoirs de stockage fixes. Prescriptions générales

R 72 (1985) 60 FRF
Hot water meters
Compteurs d'eau destinés au mesurage de l'eau chaude

R 73 (1985) 50 FRF
Requirements concerning pure gases CO, CO_2, CH_4, H_2, O_2, N_2 and Ar intended for the preparation of reference gas mixtures
Prescriptions pour les gaz purs CO, CO_2, CH_4, H_2, O_2, N_2 et Ar destinés à la préparation des mélanges de gaz de référence

R 74 (1993) 80 FRF
Electronic weighing instruments
Instruments de pesage électroniques

R 75 (1988) 60 FRF
Heat meters
Compteurs d'énergie thermique

R 76-1 (1992) 300 FRF
Nonautomatic weighing instruments. Part 1: Metrological and technical requirements - Tests
Instruments de pesage à fonctionnement non automatique. Partie 1. Exigences métrologiques et techniques - Essais
Amendment No. 1 (1994) free / *gratuit*

R 76-2 (1993) 200 FRF
Nonautomatic weighing instruments. Part 2: Pattern evaluation report
Instruments de pesage à fonctionnement non automatique. Partie 2: Rapport d'essai de modèle
Amendment No. 1 (1995) free / *gratuit*

R 78 (1989) 50 FRF
Westergren tubes for measurement of erythrocyte sedimentation rate
Pipettes Westergren pour la mesure de la vitesse de sédimentation des hématies

R 79 (in revision - *en cours de révision*)
Information on package labels
Etiquetage des préemballages

R 80 (1989) 100 FRF
Road and rail tankers
Camions et wagons-citernes

R 81 (1989) 80 FRF
Measuring devices and measuring systems for cryogenic liquids (including tables of density for liquid argon, helium, hydrogen, nitrogen and oxygen)
Dispositifs et systèmes de mesure de liquides cryogéniques (comprend tables de masse volumique pour argon, hélium, hydrogène, azote et oxygène liquides)

R 82 (1989) 80 FRF
Gas chromatographs for measuring pollution from pesticides and other toxic substances
Chromatographes en phase gazeuse pour la mesure des pollutions par pesticides et autres substances toxiques

R 83 (1990) 80 FRF
Gas chromatograph/mass spectrometer/data system for analysis of organic pollutants in water
Chromatographe en phase gazeuse équipé d'un spectromètre de masse et d'un système de traitement de données pour l'analyse des polluants organiques dans l'eau

R 84 (1989) 60 FRF
Resistance-thermometer sensors made of platinum, copper or nickel (for industrial and commercial use)
Capteurs à résistance thermométrique de platine, de cuivre ou de nickel (à usages techniques et commerciaux)

R 85 (1989) 80 FRF
Automatic level gauges for measuring the level of liquid in fixed storage tanks
Jaugeurs automatiques pour le mesurage des niveaux de liquide dans les réservoirs de stockage fixes

R 86 (1989) 50 FRF
Drum meters for alcohol and their supplementary devices
Compteurs à tambour pour alcool et leurs dispositifs complémentaires

R 87 (1989) 50 FRF
Net content in packages
Contenu net des préemballages

R 88 (in revision - *en cours de révision*)
Integrating-averaging sound level meters
Sonomètres intégrateurs-moyenneurs

R 89 (1990) 80 FRF
Electroencephalographs - Metrological characteristics - Methods and equipment for verification
Electroencéphalographes - Caractéristiques métrologiques - Méthodes et moyens de vérification

R 90 (1990) 80 FRF
Electrocardiographs - Metrological characteristics - Methods and equipment for verification
Electrocardiographes - Caractéristiques métrologiques - Méthodes et moyens de vérification

R 91 (1990) 60 FRF
Radar equipment for the measurement of the speed of vehicles
Cinémomètres radar pour la mesure de la vitesse des véhicules

R 92 (1989) 60 FRF
Wood-moisture meters - Verification methods and equipment: general provisions
Humidimètres pour le bois - Méthodes et moyens de vérification: exigences générales

R 93 (1990) 60 FRF
Focimeters
Frontofocomètres

R 95 (1990) 60 FRF
Ships' tanks - General requirements
Bateaux-citernes - Prescriptions générales

R 96 (1990) 50 FRF
Measuring container bottles
Bouteilles récipients-mesures

R 97 (1990) 60 FRF
Barometers
Baromètres

R 98 (1991) 60 FRF
High-precision line measures of length
Mesures matérialisées de longueur à traits de haute précision

R 99 (1991) 100 FRF
Instruments for measuring vehicle exhaust emissions
Instruments de mesure des gaz d'échappement des véhicules

R 100 (1991) 80 FRF
Atomic absorption spectrometers for measuring metal pollutants in water
Spectromètres d'absorption atomique pour la mesure des polluants métalliques dans l'eau

R 101 (1991) 80 FRF
Indicating and recording pressure gauges, vacuum gauges and pressure vacuum gauges with elastic sensing elements (ordinary instruments)
Manomètres, vacuomètres et manovacuomètres indicateurs et enregistreurs à élément récepteur élastique (instruments usuels)

R 102 (1992) 50 FRF
Sound calibrators
Calibreurs acoustiques

Annex (1995) 80 FRF
Test methods for pattern evaluation and test report format
Méthodes d'essai de modèle et format du rapport d'essai

R 103 (1992) 60 FRF
Measuring instrumentation for human response to vibration
Appareillage de mesure pour la réponse des individus aux vibrations

R 104 (1993) 60 FRF
Pure-tone audiometers
Audiomètres à sons purs

Annex (being printed - *en cours de publication*)
Test report format
Format du rapport d'essai

R 105 (1993) 100 FRF
Direct mass flow measuring systems for quantities of liquids
Ensembles de mesurage massiques directs de quantités de liquides

Annex (1995) 80 FRF
Test report format
Format du rapport d'essai

R 106 (1993) 100 FRF
Automatic rail-weighbridges
Ponts-bascules ferroviaires à fonctionnement automatique

Annex (being printed - *en cours de publication*)
Test procedures and test report format
Procédures d'essai et format du rapport d'essai

R 107 (1993) 100 FRF
Discontinuous totalizing automatic weighing instruments (totalizing hopper weighers)
Instruments de pesage totalisateurs discontinus à fonctionnement automatique (peseuses totalisatrices à trémie)

Annex (being printed - *en cours de publication*)
Test procedures and test report format
Procédures d'essai et format du rapport d'essai

R 108 (1993) 60 FRF
Refractometers for the measurement of the sugar content of fruit juices
Réfractomètres pour la mesure de la teneur en sucre des jus de fruits

R 109 (1993) 60 FRF
Pressure gauges and vacuum gauges with elastic sensing elements (standard instruments)
Manomètres et vacuomètres à élément récepteur élastique (instruments étalons)

R 110 (1994) 80 FRF
Pressure balances
Manomètres à piston

R 111 (1994) 80 FRF
Weights of classes E_1, E_2, F_1, F_2, M_1, M_2, M_3
Poids des classes E_1, E_2, F_1, F_2, M_1, M_2, M_3

R 112 (1994) 80 FRF
High performance liquid chromatographs for measurement of pesticides and other toxic substances
Chromatographes en phase liquide de haute performance pour la mesure des pesticides et autres substances toxiques

R 113 (1994) 80 FRF
Portable gas chromatographs for field measurements of hazardous chemical pollutants
Chromatographes en phase gazeuse portatifs pour la mesure sur site des polluants chimiques dangereux

R 114 (1995) 80 FRF
Clinical electrical thermometers for continuous measurement
Thermomètres électriques médicaux pour mesurage en continu

R 115 (1995) 80 FRF
Clinical electrical thermometers with maximum device
Thermomètres électriques médicaux avec dispositif à maximum

R 116 (1995) 80 FRF
Inductively coupled plasma atomic emission spectrometers for measurement of metal pollutants in water
Spectromètres à émission atomique de plasma couplé inductivement pour le mesurage des polluants métalliques dans l'eau

R 117 (1995) 400 FRF
Measuring systems for liquids other than water
Ensembles de mesurage de liquides autres que l'eau

R 118 (1995) 100 FRF
Testing procedures and test report format for pattern evaluation of fuel dispensers for motor vehicles
Procédures d'essai et format du rapport d'essai des modèles de distributeurs de carburant pour véhicules à moteur

R 119 (1996) 80 FRF
Pipe provers for testing measuring systems for liquids other than water
Tubes étalons pour l'essai des ensembles de mesurage de liquides autres que l'eau

R 120 (1996) 100 FRF
Standard capacity measures for testing measuring systems for liquids other than water
Mesures de capacité étalons pour l'essai des ensembles de mesurage de liquides autres que l'eau

R 121 (1996) 60 FRF
The scale of relative humidity of air certified against saturated salt solutions
Échelle d'humidité relative de l'air certifiée par rapport à des solutions saturées de sels

R 122 (1996) 60 FRF
Equipment for speech audiometry
Appareils pour l'audiométrie vocale

R 123 (being printed - *en cours de publication*)
Portable and transportable X-ray fluorescence spectrometers for field measurement of hazardous elemental pollutants
Spectromètres à fluorescence de rayons X portatifs et déplaçables pour la mesure sur le terrain d'éléments polluants dangereux

INTERNATIONAL DOCUMENTS
DOCUMENTS INTERNATIONAUX

D 1 (1975) 50 FRF
Law on metrology
Loi de métrologie

D 2 (in revision - *en cours de révision*)
Legal units of measurement
Unités de mesure légales

D 3 (1979) 60 FRF
Legal qualification of measuring instruments
Qualification légale des instruments de mesurage

D 4 (1981) 50 FRF
Installation and storage conditions for cold water meters
Conditions d'installation et de stockage des compteurs d'eau froide

D 5 (1982) 60 FRF
Principles for the establishment of hierarchy schemes for measuring instruments
Principes pour l'établissement des schémas de hiérarchie des instruments de mesure

D 6 (1983) 60 FRF
Documentation for measurement standards and calibration devices
Documentation pour les étalons et les dispositifs d'étalonnage

D 7 (1984) 80 FRF
The evaluation of flow standards and facilities used for testing water meters
Evaluation des étalons de débitmétrie et des dispositifs utilisés pour l'essai des compteurs d'eau

D 8 (1984) 60 FRF
Principles concerning choice, official recognition, use and conservation of measurement standards
Principes concernant le choix, la reconnaissance officielle, l'utilisation et la conservation des étalons

D 9 (1984) 60 FRF
Principles of metrological supervision
Principes de la surveillance métrologique

D 10 (1984) 50 FRF
Guidelines for the determination of recalibration intervals of measuring equipment used in testing laboratories
Conseils pour la détermination des intervalles de réétalonnage des équipements de mesure utilisés dans les laboratoires d'essais

D 11 (1994) 80 FRF
General requirements for electronic measuring instruments
Exigences générales pour les instruments de mesure électroniques

D 12 (1986) 50 FRF
Fields of use of measuring instruments subject to verification
Domaines d'utilisation des instruments de mesure assujettis à la vérification

D 13 (1986) 50 FRF
Guidelines for bi- or multilateral arrangements on the recognition of: test results - pattern approvals - verifications
Conseils pour les arrangements bi- ou multilatéraux de reconnaissance des: résultats d'essais - approbations de modèles - vérifications

D 14 (1989) 60 FRF
Training of legal metrology personnel - Qualification - Training programmes
Formation du personnel en métrologie légale - Qualification - Programmes d'étude

D 15 (1986) 80 FRF
Principles of selection of characteristics for the examination of measuring instruments
Principes du choix des caractéristiques pour l'examen des instruments de mesure usuels

D 16 (1986) 80 FRF
Principles of assurance of metrological control
Principes d'assurance du contrôle métrologique

D 17 (1987) 50 FRF
Hierarchy scheme for instruments measuring the viscosity of liquids
Schéma de hiérarchie des instruments de mesure de la viscosité des liquides

D 18 (1987) 50 FRF
General principles of the use of certified reference materials in measurements
Principes généraux d'utilisation des matériaux de référence certifiés dans les mesurages

D 19 (1988) 80 FRF
Pattern evaluation and pattern approval
Essai de modèle et approbation de modèle

D 20 (1988) 80 FRF
Initial and subsequent verification of measuring instruments and processes
Vérifications primitive et ultérieure des instruments et processus de mesure

D 21 (1990) 80 FRF
Secondary standard dosimetry laboratories for the calibration of dosimeters used in radiotherapy
Laboratoires secondaires d'étalonnage en dosimétrie pour l'étalonnage des dosimètres utilisés en radiothérapie

D 22 (1991) 80 FRF
Guide to portable instruments for assessing airborne pollutants arising from hazardous wastes
Guide sur les instruments portatifs pour l'évaluation des polluants contenus dans l'air en provenance des sites de décharge de déchets dangereux

D 23 (1993) 80 FRF
Principles of metrological control of equipment used for verification
Principes du contrôle métrologique des équipements utilisés pour la vérification

D 24 (1996) 60 FRF
Total radiation pyrometers
Pyromètres à radiation totale

D 25 (1996) 60 FRF
Vortex meters used in measuring systems for fluids
Compteurs à vortex utilisés dans les ensembles de mesurage de fluides

D 26 (being printed - *en cours de publication*)
Glass delivery measures - Automatic pipettes
Mesures en verre à délivrer - Pipettes automatiques

VOCABULARIES
VOCABULAIRES

V 1 (1978) 100 FRF
Vocabulary of legal metrology (bilingual French-English)
Vocabulaire de métrologie légale (bilingue français-anglais)

V 2 (1993) 200 FRF
International vocabulary of basic and general terms in metrology (bilingual French-English)
Vocabulaire international des termes fondamentaux et généraux de métrologie (bilingue français-anglais)

V 3 (1991) 80 FRF
Hardness testing dictionary (quadrilingual French-English-German-Russian)
Dictionnaire des essais de dureté (quadrilingue français-anglais-allemand-russe)

OTHER PUBLICATIONS
AUTRES PUBLICATIONS

P 1 (1991) 60 FRF
OIML Certificate System for Measuring Instruments
Système de Certificats OIML pour les Instruments de Mesure

P 2 (1987) 100 FRF
Metrology training - Synthesis and bibliography (bilingual French-English)
Formation en métrologie - Synthèse et bibliographie (bilingue français-anglais)

P 3 (1996) 400 FRF
Legal metrology in OIML Member States
Métrologie légale dans les Etats Membres de l'OIML

P 4 (1986-1981) 100 FRF
Verification equipment for National Metrology Services
Equipement d'un Service national de métrologie

P 5 (1992) 100 FRF
Mobile equipment for the verification of road weighbridges (bilingual French- English)
Equipement mobile pour la vérification des ponts-bascules routiers (bilingue français-anglais)

P 6 (1987) 100 FRF
Suppliers of verification equipment (bilingual French-English)
Fournisseurs d'équipement de vérification (bilingue français-anglais)

P 7 (1989) 100 FRF
Planning of metrology and testing laboratories
Planification de laboratoires de métrologie et d'essais

P 8 (1987) 100 FRF
Density measurement
Mesure de la masse volumique

P 9 (1992) 100 FRF
Guidelines for the establishment of simplified metrology regulations

P 10 (1981) 50 FRF
The metrology of hardness scales - Bibliography

P 11 (1983) 100 FRF
Factors influencing hardness measurement

P 12 (1984) 100 FRF
Hardness test blocks and indenters

P 13 (1989) 100 FRF
Hardness standard equipment

P 14 (1991) 100 FRF
The unification of hardness measurement

P 15 (1989) 100 FRF
Guide to calibration

P 16 (1991) 100 FRF
Guide to practical temperature measurements

P 17 (1995) 300 FRF
Guide to the expression of uncertainty in measurement
Guide pour l'expression de l'incertitude de mesure

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The OIML Bulletin is a forum for the publication of technical papers and diverse articles addressing metrological advances in trade, health, environment and safety – fields in which the credibility of measurement remains a challenging priority. The Editors of the Bulletin encourage the submission of articles covering topics such as national, regional and international activities in metrology and related fields, evaluation procedures, accreditation and certification, and measuring techniques and instrumentation.

Authors are requested to submit a double-spaced, titled manuscript and accompanying visual materials (photos, illustrations, slides, etc.), together with a disk copy in one of the following formats: WordPerfect 5.1, ASKII MS-DOS, Word 6.0 (or previous versions for PC), or Quark XPress for Macintosh. Authors are also requested to send a passport-size, black and white identity photo for publication. Papers selected for publication will be remunerated at the rate of 150 FRF per printed page, provided that they have not already been published in other journals. The Editors reserve the right to edit contributions for style and space restrictions.

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Printing error

Readers may have noticed that the Editorial in the July 1996 edition of the BULLETIN (Volume XXXVII, Number 3) was not printed in the correct font.

The Editors of the BULLETIN would like to point out that this error did not appear in the printer's final proof and that due to time constraints, it was decided to distribute it without a reprint.

The printer would like to apologise for this error and trusts that no inconvenience was caused to readers.