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New Directions – The Status of Mathematics and Software in Legal Metrology: recommendations for the Software Support for Metrology programme 2004-2007

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ABSTRACT

This report describes the status of the mathematics and software used in the Legal Metrology area. This is a report produced for the NMS Software Support for Metrology (SS*f*M) programme, 2001-2004, as the result of one of five studies conducted under the New Directions project. This study aimed to identify requirements, techniques and problems that should be addressed in the formulation of the SS*f*M 2004-2007 programme, in order to support the NMS Legal Metrology programme in its use of mathematics, statistics and software.

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1. Introduction

The National Weights & Measures Laboratory (NWML) is an Executive Agency of the Department of Trade & Industry, and is responsible for ensuring measurement in the UK is accurate, fair and legal. NWML has the lead responsibility for national policy on measuring instruments in use for trade and represents UK interests regarding the implementation of European Directives on measuring instruments The Laboratory is also responsible for the examination and approval of certain types of weighing and measuring equipment to be used for trade.

The Software Support for Metrology (SS*f*M) New Directions project's Legal Metrology study was conducted by NWML under contract to NPL. That study has resulted in this report.

The purpose of this report is to inform interested parties about the current status of the use of software and mathematics within the Legal Metrology field, particularly within the NMS Legal Metrology programme, and to identify what generic support would be most appropriate from the SS*f*M programme. It also reports on attempts to identify any best practices within the Legal Metrology field that might have application in other metrology fields. It reports the result of attempts to identify potential case studies that could be undertaken within the SS*f*M programme. The report should enable manufacturers of measurement systems for use in a legal metrology context to assess their position compared to the current status.

Thus, the study addressed topics such as modelling, validation, development tools, and standards. We also investigated the position of the Regulators and their requirements in these fields. A questionnaire was specifically designed for the study and sent out to 131 contacts by e-mail. With the fast moving pace of the software world, it is not surprising that 12 were returned as undeliverable, leaving 119 reaching their destinations. Of these, only 10 were returned with data that could be included in the study. This low response should be taken into account when drawing conclusions from this report.

2. Scope of Legal Metrology

The study concentrated on the areas of legal metrology of relevance to the NMS Legal Metrology programme. This included weights and measures, utility meters such as gas, electricity and water, breath analysers and exhaust gas analysers. The weights and measures area also extended to the providers of management systems supporting the measurement, for example the control and point of sale equipment found in garage forecourts and at supermarket checkouts.

However, of the ten answered questionnaires received, the respondents comprised 5 weighing machine manufacturers, 2 fuel dispenser manufacturers, 2 electricity meter manufacturers and one EPOS (electronic point of sale) system manufacturer. It should be noted that, in addition, both fuel dispenser manufacturers also make EPOS systems.

3. Modelling techniques

Types of data

There are three categories of measurement data sets:

1. Discrete measurement data, which means:
   a) data obtained by sampling a discrete variable: e.g., a variable that may take only integer values such as in counting processes, and

b) data obtained by sampling a continuous variable.

2. Continuous measurement signal, which means an analogue signal prior to any analogue to digital conversion, which would result in data of type 1 b).
3. Hybrid measurement data composed of both discrete and continuous data sets.

Modelling Types

There are three categories of model:

1. Discrete models in which the outputs of the measurement system are related to measurements of its inputs by a system of algebraic equations;
2. Continuous models in which the outputs of the measurement system are related to measurements of its inputs by a system of differential equations;
3. Hybrid models in which the outputs of the measurement system are related to measurements of its inputs by a system composed of both algebraic and differential equations.

It is appropriate to distinguish here between the nature of the model and the approach to solving the model (which for a continuous model typically also involves solving algebraic equations).

Given infinite precision arithmetic, the set of equations derived from a discrete model can be solved exactly. This is not the case for a continuous model, which, typically, requires approximations to be made, for example, in terms of domain discretisation.

3.1 Discrete Modelling

Four respondents reported utilising discrete modelling techniques. Three of these were manufacturers of weighing equipment and one a manufacturer of retail electronic point of sale equipment (EPOS). One of the weighing machine manufacturers specified the use of digital filters for modelling. Another weighing machine manufacturer used discrete modelling to look at the physical performance of automatic weighing machines using Excel spreadsheets.

3.2 Continuous Modelling

No measurement system manufacturers reported the use of continuous modelling techniques. One manufacturer of retail electronic point of sale equipment (EPOS) reported using this technique.

3.3 Uncertainty and statistical modelling

The estimation of measurement uncertainties in the metrology area follows the principles of the ISO Guide to the Expression of Uncertainty in Measurement [1] and UKAS document M3003 [2]. UKAS have also issued supplementary guides for uncertainty in testing and EMC testing, reference LAB 12 [3] and LAB 34 [4] respectively.

However, there are many areas that are not specifically addressed and this includes the effect the reliability of software might have on the uncertainty of measurement. UKAS do promote the use of ‘TickIT’ as a benchmark for software and details of this can be found in their leaflet CIS1 [5].

Uncertainty in flow measurement has been governed historically by ISO 5168. The standard used over many years has been withdrawn and a revised version issued as a technical report (BS ISO 5168 TR[6]). As this revision is based on the separate derivation of systematic and random uncertainties, ISO was only prepared to issue it as a technical report until a further revision brings it in line with current recognised practice. Work is in hand to revise the standard.

Three respondents reported using uncertainty evaluation, one each from weighing, electricity meter, and EPOS manufacturing. The electricity meter manufacturer claimed to use uncertainty evaluation to model product life using Siemens Norm.

3.4 Data visualisation

The responses lead us to believe that data visualisation is carried out at a fairly simple, 2-dimensional level. This primarily involves producing plots of measurement output against standard input and utilising common spreadsheet packages.

For flow inter-comparison work, Youden plots have previously been reported, but were not mentioned by any of the respondents to this study. They are seldom used without accompanying calibration curves.

More detail can be found in previous reports on electrical metrology in CISE 31/99 [7] and flow metrology in CISE 38/99 [8].

Two weighing machine manufacturers and one EPOS manufacturer reported using visual modelling and data visualisation. One of the weighing machine manufacturers reported using the Lotus 123 spreadsheet for data visualisation.

3.5 Data fusion

CISE 38/99 [8] reported that

> *"Data fusion is becoming a feature of many modern flow meters and flow sensors. In general the number of inputs is small and the data processing relatively simple. Even with the simple systems making the software interact in real time with the user is a problem. Many flow applications are batching systems and the dynamics of this seem to be very difficult to control.*
>
> *Data Fusion was recognised in the Foresight Programme as one of the most important topics in industrial measurement affecting flow measurement and process control. As a result an NMS Flow Programme project was formulated and completed in 1998. SIRA was the main contractor and the final report has been produced. The full report is available [9]."*

None of the ten respondents reported the use of data fusion. It should be noted that manufacturers of fuel dispensers traditionally use well proven positive displacement piston meters for simple quantity measurements, limited by a minimum quantity and within flow rates limited by the system and regulatory approval. There have been some recent approvals for small twin-screw meters, or axial flow meters, but these technologies lend themselves to simple pulse counting for volume determination.

3.6 Characteristics modelled and techniques used

One of the weighing machine manufacturers reported using MathCAD, Excel and Access for modelling the following:

- Weight variation due to wheel irregularity for weighing rail wagons.
- Loading control loop behaviour.

- Speed related adjustment visualisation.

The EPOS manufacturer reported using all the modelling techniques other than data fusion to model forecasting by regression analysis using tools developed in house.

3.7 Future use of modelling and support required

No respondent anticipated using additional modelling techniques in the future, eight replying with a definite 'No', and two failing to comment.

They were less sure when asked if industry needed support for these techniques. Two said 'No', two did not know, five did not answer the question, and only one weighing machine manufacturer said support was needed.

4. Validation and testing

Half of the respondents did not report any form of validation or testing, and only one of these five indicated the possible future use of validation of software within measurement systems. Of the remaining four, two indicated they did not anticipate using such techniques and two did not respond to the future use question.

4.1 Numerical software testing

Numerical software testing was qualified in the questionnaire by the example of functions in spreadsheets or other mathematical packages. Two weighing machine manufacturers and one fuel dispenser manufacturer indicated they used such methods.

4.2 Model validation

Only one of the ten respondents, a weighing machine manufacturer, said that they used model validation.

4.3 Validation of software within measurement systems

Two fuel dispenser manufacturers, an electricity meter maker and a weighing machine manufacturer indicated they validated their measurement software.

However both of the fuel dispenser manufacturers stated that they did this by practical or manual verification of the dispenser. One of these indicated they utilised Excel and it is likely that this is used to confirm the price to pay algorithm. This computes the price to pay from the dispensed volume and the unit price of the product.

The electricity meter manufacturer uses 'Black box' testing, 'White box' testing, and code level validation with break points to carry out their software validation, using the manufacturers kit for the micro-controller used in their design.

4.4 Validation of simulated instruments

Only two of the ten respondents indicated using validation of simulated instruments, one manufacturer of fuel dispensers and one weighing machine manufacturer. Of the remaining eight, one reported this technique was not applicable to his product and the rest answered 'No'.

4.5 Validation of self-validating or self-calibrating instruments

All ten respondents answered that they did not use validation of self-validating or self-calibrating instruments. This is probably simply a reflection of the fact that the trade measurement area is very conservative and there are very few self-validating or self-calibrating trade instrument in existence.

4.6 Other techniques and packages used

In addition to the techniques individually identified above, one weighing machine manufacturer identified the use of Excel spreadsheets and another identified 'Pro Engineer' as a commercial package being used.

4.7 Future support for validation techniques

Asked if industry needed support regarding these techniques, half the respondents chose not to answer the particular question. Of the remainder, two replied 'No', two did not know, and only one thought industry required support. This is very curious, bearing in mind that measurement system software validation in support of WELMEC 7.1 (see section 6.1.2 below) has been the major technical topic discussed within the Legal Metrology Software Club run by NWML. It suggests that the respondents may not have understood the terminology used in this portion of the questionnaire.

5. Software and algorithm development techniques

5.1 Software development techniques

Although half of the respondents reported using software development methods, none of the manufacturers replying to the questionnaire anticipated they would be using any new techniques in the future. One responded that they 'did not know', implying a possibility of utilising new techniques in the future. Similarly, when asked if they thought industry needed support in this area, five declined to answer, three said 'no', one 'did not know', and only one weighing machine manufacturer replied 'yes'.

Table 1 gives an overview of the software development replies to the questionnaire.

Technique / Manufacturer	Software development	Numerical Analysis	Software reuse	Virtual Instruments	Future use?	Support needed for industry?
Weigh 1	Y	Y	Y	N	N	DNK
Weigh 2	N	N	Y	N	-	-
Weigh 3	Y	Y	Y	N	N	N
Weigh 4	Y	N	N	N	-	-
Weigh 5	N	Y	N	N	N	N
Fuel Dispenser 1	N	N	Y	N	N	N
Fuel Dispenser 2	Y	Y	Y	Y	DNK	-
Electricity meter 1	N	N	Y	N	-	-
Electricity meter 2	Y	N	Y	N	N	N
EPOS 1	-	-	-	-	-	-

Table 1 – Software development techniques used

Key: **Y** **yes**
N **no**
DNK **do not know**

5.1.1 Languages used

The software languages used by the respondents are detailed in Table 2.

Language/ Manufacturer	C	C++	Assembler	Visual Basic	Basic	PLM
Weigh 1	X	X		X		
Weigh 2	X	X	X			
Weigh 3		X				
Weigh 4	X			X		
Weigh 5	X					
Fuel Dispenser 1	X					
Fuel Dispenser 2	X		X(Z80)		X	X
Electricity meter 1	X(ANSI)		X			
Electricity meter 2	X		X			
EPOS 1						

Table 2 – Software languages used

5.1.2 Packages and tools used

Not all respondents chose to answer this question. Two of the manufacturers using C++ use the Borland product. One of the users of C uses 'Metaware High C' and another uses the 'Keil Compiler'; the remainder did not identify a specific product. An electricity meter manufacturer who uses C and assembler uses his microprocessor supplier's kit. One of the visual basic users utilises 'Visual Studio 6'. One of the fuel dispenser manufacturers, who uses Z80 assembler, PLM, C and Basic, reported using Microsoft and Intel packages.

Only four manufacturers described the techniques they use to construct their software and some of these responses were not very specific. A weighing machine manufacturer who utilises Borland C++ uses object decomposition. One of the fuel dispenser manufacturers, who uses C without identifying a commercial package, uses "consolidated main code with optional modules". The other fuel dispenser manufacturer reported using an "ISO 9001:2000 development cycle". The electricity meter manufacturer, who uses C and assembler with their microprocessor supplier's kit, reported using "internal software methods".

5.2 Numerical analysis for algorithm development

Numerical analysis is the area of mathematics and computing that deals with the generation of algorithms to solve numerical problems with appropriate accuracy in the computations. Such algorithms may, for example, be used for solving problems involving continuously changing variables in real world applications. Many software packages, such as spreadsheets come with numerical algorithms of unknown quality embedded in them.

Four manufacturers reported using numerical analysis, three of these were manufacturers of weighing machines, and the fourth was a fuel dispenser manufacturer.

Three manufacturers have reported using Excel and one Lotus 123.

5.3 Software and algorithm reuse

The reuse of software and algorithms can provide significant cost savings when developing new products. The use of software libraries or libraries of subroutines has been carried out for several decades. To a certain extent this has been supplemented by the use standard formulae and mathematical calculations embedded in spreadsheets. However, reuse can also be made of macros and visual basic within spreadsheets.

Seven of the ten respondents confirmed that they reuse their software.

5.4 Virtual instruments

A virtual instrument (VI) is the name given to reusable software running on a general-purpose computer (e.g. a PC) to control a piece of equipment possibly with its own embedded software. The computer provides the user interface and data processing, with the basic measurements carried out by plug-in boards or stand-alone instruments. In the absence of a standard definition of a VI, the SS*f*M programme defines a VI as follows:

> *A VI is a reusable measurement instrument created by adding hardware and/or software to a generic computer, typically a PC, Mac or workstation, and which uses a computer screen to provide the visual interface to the instrument.*

Various software environments exist to help construct VIs, such as National Instruments' LabVIEW, Microsoft C++ and various types of Basic, including Visual Basic.

The use of computers to control instruments provides flexibility and reduced cost, but often at the expense of rigorous design, verification and validation. The first SS*f*M programme produced a guide on virtual instruments (SS*f*M Best Practice Guide No. 2), which has recently been superseded by a guide on test and measurement software (SS*f*M Best Practice Guide No. 12), the latter still including explicit guidance on virtual instruments. These guides can be downloaded from www.npl.co.uk/ssfm/download/bpg.html.

LabVIEW is a graphical software system for developing virtual instruments via instruments with IEEE-488 (GPIB), RS-232/422 and modular (VXI or CAMAC) interfaces, as well as plug-in I/O boards. LabVIEW programs, which are actually called "virtual instruments", are created using icons instead of text-based code. A LabVIEW VI consists of a front panel and a block diagram. The front panel is the user interface and has knobs, switches etc. The block diagram consists of icons that operate on data from hardware connected by wires.

Only one respondent, a fuel dispenser manufacturer, reported the use of virtual instruments.

5.5 Future support for software and algorithm development techniques

It was disappointing that none of the manufacturers forecast any additional future use of the development techniques identified in the questionnaire. This was despite having typically reported only about 50% use of software development, numerical analysis and software reuse; and only one reported using virtual instruments. This may be because they are at the low software end for some of the simple trade measuring instruments. However, as a regulator, NWML is constantly seeing more sophisticated products. The software around the measuring instrument may remain simple but more customer, management, reporting, and international market options are being added. This indicates a need for industry to be made more aware of the benefits of these development techniques to remain competitive in the international market place.

6. Support for Standards and Regulations

The questionnaire asked respondents if they constructed their software using guides or standards as a basic design requirement. Six respondents replied that they did; three, all weighing machine manufacturers, replied that they did not. The EPOS manufacturer did not respond to the question but had previously stated that their software suppliers used the WELMEC guides. Details of the relevant guides and standards follow.

6.1 Use of WELMEC guides

WELMEC is a co-operation between the legal metrology authorities of the Member States of the European Union and EFTA. It has produced a number of guides including two that relate directly to software used in legal metrology. More information about WELMEC and the guides it produces can be found on their web site at: www.welmec.org.

6.1.1 WELMEC guide 2.3

The EC Directive 90/384/EEC states some essential requirements for the protection against changes, manipulation or fraudulent use of non-automatic weighing instruments (NAWIs) which, in principle, have to be applied also to the software controlling these instruments:

(i) Directive 90/384/EEC, Annex I, No 8.1: *Design and construction of the instruments shall be such that the instruments will preserve their metrological* *qualities when properly used and installed, and when used in an environment for which they are intended...*

(ii) Directive 90/384/EEC, Annex I, No 8.5: *The instruments shall have no characteristics likely to facilitate fraudulent use, whereas possibilities for unintentional misuse shall be minimal. Components that may not be dismantled or adjusted by the user shall be secured against such actions.*

(iii) Directive 90/384/EEC, Annex II, No. 1.7: *The applicant shall keep the notified body that has issued the EC type-approval certificate informed of any modification to the approved type...*

WELMEC working group 2 has taken these essential requirements and has produced a guide to allow a uniform interpretation with regard to intelligent, user-accessible (free programmable) peripheral devices or modules of NAWIs, such as PC-based indicators, data storage devices or EPOS terminals.

As WELMEC 2.3 is a guide for software in non-automatic weighing instruments, then we should only consider the five weighing machine manufacturers and EPOS manufacturer. Of these, three of the weighing machine manufacturers and the EPOS manufacturer reported following WELMEC 2.3. The two who do not utilise this guide are involved in automatic weighing and therefore it could be considered that all of the NAWI manufacturers responding follow WELMEC 2.3.

6.1.2 WELMEC guide 7.1

The remit of the new WELMEC working group 7, "Software", is to harmonise the type approval practice of the European Notified Bodies with respect to the software of measuring instruments covered by the Measuring Instruments Directive (MID).

The MID will contain "Essential requirements" (Annex I) for measuring instruments used for legal purposes. Some of these essential requirements can be directly applied to the software controlling these instruments:

(i) MID, Annex I, No. 8.3: *Software that is critical for metrological characteristics shall be identified as such and shall be secured. Its identification shall be easily available. Evidence of an intervention shall be available for a reasonable period of time.*

(ii) MID, Annex I, No. 8.4: *Measurement data, software that is critical for measurement characteristics and metrologically important parameters stored or transmitted shall be adequately protected against accidental or intentional corruption.*

Other essential requirements can be applied to both hardware and software of a measuring instrument, e.g.:

(iii) MID, Annex I, No. 7.1: *A measuring instrument shall have no feature likely to facilitate fraudulent use, whereas possibilities for unintentional misuse shall be minimal.*

(iv) MID, Annex I, No. 8.1: *The metrological characteristics of a measuring instrument shall not be inadmissibly influenced by the connection to it of another device, by any feature of the connected device itself or by any remote device that communicates with the measuring instrument.*

(v) MID, Annex I, No. 12: *A measuring instrument shall be designed so as to allow ready evaluation of its conformity with the requirements of this directive.*

WELMEC Guide 7.1 tries to make the reader aware of the fact that only testing the metrological performance of an instrument without taking care of the software controlling the instrument is not adequate for modern, microprocessor-controlled or PC-based measuring instruments. It acknowledges that it is often the software and its integrity that determines the metrological properties and reliability of an instrument. As the Guide covers very different categories of measuring instruments it can give only the basics of software examination. It is intended to be successively amended by specific annexes for each kind of measuring instrument, similar to the specific annexes contained in the MID.

This Guide is intended to support a uniform software examination in Europe and to make the result of an examination estimable for the manufacturer. The Guide is, however, not mandatory, even for those instruments that are covered by the MID.

It is interesting to note that the MID is still at a draft stage and will not come into force until 2 years after it has been agreed and comes into European legislation. However, six of the ten respondents reported that they are encouraged to, or do, comply with the Guide. These six include all the non-weighing industries, that is, the 2 electricity meter manufacturers, the 2 fuel dispenser makers, and the EPOS manufacturer.

Overall eight of the ten respondents reported using one or both of the WELMEC guides on software.

This is at odds with the apparent lack of interest from respondents in the validation and testing guidance produced by the SS*f*M programme. Perhaps it needs to be made clear that software examination and software validation are essentially the same thing. Thus, validation techniques recommended by the SS*f*M programme will be means of achieving software validation in accordance with the WELMEC Guides.

6.2 Requirements for standard algorithms

Some metrology specific standards specify algorithms or mathematical procedures. Other standards, for example those concerned with uncertainties, also include mathematical procedures. In addition, there is often a need to promote standard approaches to common routines, such as those concerned with regression or curve fitting. Many existing standards specify or recommend mathematical, statistical or computational analysis that is required in complying with the standard. Examples are:

1. Calibration curve fitting using polynomials in flow measurement.
2. The estimation of the departure from perfect form (“flatness”, “roundness”, etc.) by determining representations of standard shapes in dimensional metrology.
3. The determination of uncertainties in electromagnetic compatibility work.

When asked if they used standard algorithms, nine of the respondents replied ‘no’ and the tenth declined to answer the question.

6.3 Standard approaches to uncertainty

The evaluation of uncertainty can be related to modelling, in that the availability of a practical model, together with statistical knowledge of the system inputs provides the information that is needed to evaluate the uncertainties of the system outputs. Inputs can refer to the measurement data together with any other influence factors such as temperature, humidity or calibration constants; outputs refer to the model parameters and any functions of them that would represent the required measurement system and results. It is therefore possible to have a standard approach or model for a particular measurement system. In the first SS*f*M programme, work took place on uncertainty evaluation and an advanced best-practice guide and software specifications were provided. The guide is SS*f*M Best Practice Guide No. 6, which can be downloaded from: www.npl.co.uk/ssfm/download/bpg.html.

For a simple introduction to the subject of uncertainty evaluation, as is more appropriate for most organisations in the legal metrology field, the SS*f*M programme recommends the use of the introductory Good Practice Guide produced under *Competing Precisely*, which can be found at: www.npl.co.uk/npl/publications/good_practice/uncert/chap2.html.

None of the ten manufacturers use a standard approach to uncertainty evaluation. Eight declared a simple 'no', one fuel dispenser manufacturer 'did not know', and the EPOS manufacturer did not answer. This may be partly due to the fact that the target audience of the questionnaire were all manufacturers. We would expect a significantly different answer from test and calibration laboratories as their accreditation bodies would require a more rigorous approach to uncertainty evaluation.

6.4 Other guides and standards

The other standards and guides most commonly identified were the OIML (the International Organisation for Legal Metrology) Recommendations for the particular instruments being manufactured. These recommendations aim at producing model regulations, which provide Members with an internationally agreed basis for the establishment of national legislation concerning various categories of measuring instruments.

OIML was established in 1955 in order to promote the global harmonization of legal metrology procedures. Since that time, the OIML has developed a worldwide technical structure that provides its members with metrological guidelines for the elaboration of national and regional requirements concerning the manufacture and use of measuring instruments for legal metrology applications.

OIML has become aware that most of its recommendations do not currently address software aspects and it has therefore set up sub-committee TC5/SC2 to address this. Its scope is to study the issues related to computerised instruments, to their software and the transmission and storage of data, and:

- To review the requirements existing in present OIML International Recommendations and International Documents.
- To review the relevant normative documents and the work ongoing in other organisations.
- To elaborate specifications to be taken into consideration in the specific OIML International Recommendations.
- To elaborate guidance documents for type approval activities and initial verification.

The OIML Recommendations that were identified by the respondents to the questionnaire were:

R50	Continuous totalising automatic weighing instruments (belt weighers).
R51	Automatic catch-weighing instruments.
R76	Non-automatic weighing instruments.
R106	Automatic rail-weighbridges.
R117	Measuring systems for liquids other than water

In addition to the OIML Recommendations, the following standards were identified:

- EN 45501 The European Standard for Non-Automatic Weighing Instruments, which is almost identical in its technical requirements to OIML R76.
- IEC 61036 Alternating current static watt-hour meters for active energy (classes 1 and 2)
- IEC 62059 Electricity metering equipment (a.c.) - Dependability.

It should be noted that the IEC is working on:

- Draft IEC 62059-51: Electricity metering equipment (a.c.) - Dependability - Part 51: Software aspects of reliability.

6.5 Regulatory control

The questionnaire asked for comment on the regulators' level of software examination and control. Perhaps not surprisingly, as the questionnaire was being co-ordinated by the United Kingdom's primary metrology regulator, seven manufacturers did not respond to the question. None of the weighing machine manufacturers or the EPOS manufacturer responded.

Both of the fuel dispenser manufacturers responded, one saying the control and software examination was 'adequate'. The other said NWML were 'aiming towards WELMEC 7.1 and taking a practical approach to control'.

One of the two electricity manufacturers responded saying that it only extends to a black-box test.

6.6 Future support for standards and regulations

Many modern instruments are PC-based, but even dedicated designs often contain large amounts of embedded software, which provides them with a wide range of options, interfaces and changeability. PC-based systems almost always use commercially available operating systems. This can make it more difficult when the software has to be approved by the regulator. The WELMEC guides provide a means of satisfying the regulator's requirements and it was good to see that 80% of respondents reported using the guides. However, with the low response to the questionnaire mainly from some of the larger manufacturers, we still believe that smaller manufacturers may need to be made more aware of these documents. This may be even more applicable where manufacturers sub-contract their software supply to third parties.

Another area that may be of use to both industry and regulators is the comparison of WELMEC 7.1 with other existing international standards. Validation systems already exist for some of these standards and they may provide a more cost effective and efficient means of gaining approval for legal metrology software.

7. Support for measurement and calibration processes

7.1 Management systems

None of the respondents used LIMS (Laboratory Information Management Systems) and this is probably due to them being manufacturers rather than calibration or test laboratories. The alternatives offered for processing calibration and test data were 'manual', 'regulated by OFGEM and implemented through internal procedures', 'company procedures' and 'the calibration itself'. One replied that no method was used and four declined to answer the question.

When asked what were the main advantages and disadvantages of the systems they used, only two provided useful answers. The weighing company using a manual system believed it offered 'value for money'. The fuel dispenser manufacturer using company procedures believed they had control over the system but that it was time-consuming.

7.2 Quality systems

ISO 9000 is the predominant quality system in use, two companies citing ISO 9000, and three ISO 9001. One listed BS 5750. All of these had accredited quality systems. Of the others, one stated they did not follow a quality system standard and the remaining three declined to answer, strongly suggesting they do not.

7.3 Format standards for measurement data

Format standards or the lack thereof do not appear to be a problem for the responding manufacturers. Six stated that they do not have problems or requirements for format standards for measurement data. This may be because they manufacture stand-alone systems and can use any data format that suits them. However, many manufacturers have their own proprietary protocols for data transmission and will release them to other manufacturers when it is commercially advantageous to do so. There was a move throughout the 1990s by the oil companies to introduce a standard for forecourts so they could mix and match from various equipment suppliers, or upgrade parts of systems, without incompatibility problems. It is known as IFSF, the International Forecourts Standards Forum, and more information can be found at: www.ifsf.org. However, this system has not replaced all the proprietary protocols but, being backed by most of the major oil companies, is likely to increase its share of the market in time.

7.4 Use of the Internet in calibration services

Asked if they needed remote access to calibration or measurement services via the Internet, the majority, six, replied they did not. Two weighing machine manufacturers replied that they could possibly use such a service. It would seem likely that if manufacturer's efficiency could be improved, or their costs reduced, then many businesses would use such facilities. However, it does not appear to be a major concern of the respondents at this time. Two of the respondents did not answer this question.

When asked what particular services they would like to be provided via the Internet, none of the manufacturers identified any requirement.

7.5 Future support for measurement and calibration processes

With the introduction of the MID, many alternative routes to conformity assessment will be allowed. Many of these will rely on self-declaration based on quality assurance procedures; others will depend on third party testing carried out by a notified body. This is likely to result in manufacturers and test houses seeking to become accredited or designated by the member states to carry out these tasks. There will, therefore, be a possible need for support for these manufacturers and test houses to demonstrate the calibration and traceability of their in-house test procedures.

Similarly these manufacturers and test houses may need to manage and record information related to production, test and calibration in a more controlled and efficient way, to meet the requirements of their regulators and accreditation bodies. There is probably an opportunity to introduce them to LIMS, if not to consider their specific needs in relation to facilities offered by current LIMS systems.

8. Best practices and Future Activities

8.1 Best practices and case studies

The questionnaire asked addressees to identify any practices regarding the use of mathematics or software, which they regarded as best practice and which might benefit other fields of measurement. Unfortunately the respondents failed to identify any best practices. Six simply replied they were not aware of any examples and the remaining four did not respond to the question.

Similarly the questionnaire requested information on any case studies that it would be beneficial to include within the future SSfM programme. This resulted in a similarly poor response, four respondents simply stated that they did not know of any suitable case studies and the remaining six failed to respond to the question.

8.2 Future Metrology and SSfM programme topics

The questionnaire asked addressees to identify any additional subjects that needed support from their regulator. The regulators concerned are NWML and OFGEM. None of the respondents identified any topics for additional support.

Similarly they were requested to identify areas that needed support from the SSfM programme. None were identified.

A major problem that exists is the widening gap between the software knowledge of the regulators and requirements of the guides and legislation. This is not only a problem in the United Kingdom, as many other regulators around the world admit to being in the same situation. What happens in many cases is that the regulator primarily relies on a declaration made by the manufacturer. In Germany, PTB has set up a department to offer a software validation service. OIML has set up TC5/SC2 but this in itself will not do anything to close the gap between regulator knowledge and requirements. One of the main problems is the cost of software validation. Type approval has become very competitive throughout Europe and regulators are afraid of charging the real cost of software validation in case they lose their customers to their competitors. Opportunities exist to investigate the solutions to this problem, whether it be training the regulators, providing a centralised validation service, providing validation tools or some other solution.

Currently liaison is carried out between NWML and NPL regarding software in legal metrology measuring instruments. NPL has attended, and participated by presenting papers, at NWML’s Legal Metrology Software Club, which includes other regulators as members. This liaison and support needs to continue with NPL providing high level software knowledge to support the regulators’ legal metrology knowledge and pragmatic approach.

9. Summary of Recommendations

9.1 Future support for software and algorithm development techniques

No manufacturers forecast any additional future use of development techniques despite having typically reported only about 50% use of software development, numerical analysis and software reuse; and only one reported using virtual instruments. Industry needs to be made more aware of the benefits of these development techniques to remain competitive in the international market place.

9.2 Future support for standards and regulations

The increasing complexity of modern instruments can make it more difficult when the software has to be approved by the regulator. The WELMEC guides provide a means of satisfying the regulator's requirements but small manufacturers, and third party software suppliers, need to be made more aware of these documents.

Another area that may be of use to both industry and regulators is the comparison of WELMEC 7.1 with other existing international standards. Validation systems already exist for some of these standards and they may provide a more cost effective and efficient means of gaining approval for software.

9.3 Future support for measurement and calibration processes

With the introduction of the Measuring Instruments Directive many alternative routes to conformity assessment will be allowed, including self declaration based on quality assurance procedures, and third party testing carried out by a notified body. There will, therefore, be a need for support for these manufacturers and test houses to demonstrate the calibration and traceability of their in-house test procedures.

Similarly these manufacturers and test houses will need to manage and record information related to production, test and calibration in a more controlled and efficient way to meet the requirements of their regulators and accreditation bodies. There is a need to introduce them to LIMS.

9.4 Future Metrology and SSfM programme topics

A major problem is the widening gap between the (relative lack of) software knowledge of the regulators and the (increasingly onerous) requirements of the guides and legislation. One of the main problems is the high cost of software validation. Opportunities exist to investigate the solutions to this problem, whether it be training the regulators, providing a centralised validation service, providing validation tools or some other solution.

10. Acknowledgements

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Appendix 1: Glossary of abbreviations

CAD Computer-aided design

CAE Computer-aided engineering

CAM Computer-aided manufacturing

CAMAC CAMAC is an international standard of modularised electronics as defined by the ESONE Committee. Its function is to provide a scheme to allow a wide range of modular instruments to be interfaced to a standardised backplane.

EPOS Electronic point of sale

IEEE 488 A standard interface bus for programmable instruments. Also known as the GPIB, General Purpose Interface Bus; or the HPIB, the Hewlett Packard Interface Bus.

LabVIEW A graphical software system for developing virtual instruments via IEEE-488 (GPIB), RS-232/422 and modular (VXI or CAMAC) instruments as well as plug-in I/O boards.

LIMS Laboratory Information Management Systems

MID Measuring Instruments Directive. A draft EC new approach directive whose scope will cover a number of different measuring instruments.

PLM Product Lifecycle Management. An integrated manufacturing tool encompassing CAD, CAE, CAM software and hardware. IBM with Dassault, and PTC with EDS are providers.

VXI An open standard platform for commercial ATE (automatic test equipment).

WELMEC A co-operation between the legal metrology authorities of the Member States of the European Union and EFTA

Appendix 2: Bibliography

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