

REPORT

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CALIBRATION ISSUES FOR MEASUREMENT OF MOISTURE IN MATERIALS

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ABSTRACT

This summary report details practical measurements made at the National Physical Laboratory (NPL) using instrumentation to measure the moisture content of selected materials. The experience gained in this new field of measurement for NPL has enabled measurement issues to be identified and uncertainty budgets to be evaluated for the selected techniques. Approaches to further work are identified which seek to improve traceability for the selected methods of moisture measurement in materials. This work constitutes Deliverable 2 of Project UP10 of the Department of Business Innovation and Skills' National Measurement System Programme for Materials and Thermal Metrology, 2005-2010.

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EXECUTIVE SUMMARY

This report covers work at NPL on measurement of moisture content of materials, forming Deliverable 2 of Project UP10 of the Department of Business Innovation and Skills' National Measurement System Programme for Materials and Thermal Metrology, 2005-2010.

NPL has put in place facilities for making moisture content measurements, and this capability has been trialled during the course of the project. Demonstration measurements have been made on a variety of materials. The work covers both water content, and more general moisture content (including other volatiles).

The project has been used to gain a useful level of experience in making these measurements, while at the same time offering a trial measurement service supported by the project, to benefit other work inside and outside NPL.

Provisional uncertainty analyses have been made for several instruments. This contributes to understanding of the measurement techniques, and highlights areas where measurement methods or traceability can potentially be improved. There is scope to develop these uncertainty estimates further, and to disseminate this knowledge to improve user understanding of measurement uncertainty in this field.

Some of the difficulties with measurement traceability for moisture content measurements are well known (such as ambiguous definition of moisture, limited certified reference materials (CRMs), and material-specific problems). There is a need for user awareness of the features and limitations of existing provision of measurement traceability. Further support for moisture measurement traceability could be achieved through a number of possible future developments which, if successful, could address shortcomings of CRMs available to date.

It remains a challenge that different techniques and applications vary in which (non-water) components of moisture are detected, and standardisation of measurements and calibrations must continue to accommodate some of these differences.

1. INTRODUCTION

Moisture adversely affects many materials and products in their dimensional stability, mechanical strength, microbial activity, corrosion and other chemical stability, handling characteristics, thermal properties and more. The consequences of this impact on the thermal efficiency of buildings, materials processing and the product quality of foods, pharmaceuticals, agriculture, solid and liquid fuel, concrete, timber and chemicals. Moisture is critical to the performance of many materials, particularly coatings and adhesives, and hence reliable moisture measurement can be key to innovation in a wide variety of areas. Despite widespread interest in measuring material moisture content, there is only limited measurement traceability infrastructure currently in place.

The measurements needed vary significantly. In simple cases, the quantity of interest is average or bulk moisture content. In other cases it is surface or near-surface moisture. Some users would like to understand the moisture profile in a material, and real-time changes in moisture profile, which are far more challenging to measure. The component measured may be water, specifically, or moisture more widely defined to include other volatile substances.

NPL has established a facility for making measurements of moisture content using a variety of physical techniques and has investigated issues concerning traceability, calibration and uncertainty through practical measurements made on a wide variety of materials.

The range of instrumentation selected for this new measurement facility was chosen to enable NPL to investigate and discover potential problems that may be faced in laboratories and industry when measurements of moisture content are made through a variety of physical techniques. Issues surrounding calibration and traceability were encountered when using the instruments and initial uncertainty budgets were evaluated from the information gathered while making practical measurements.

Gravimetric loss-on-drying instruments that are representative of those used in industrial laboratories were chosen, because this is a widely used reference method. Also selected was an instrument that enabled physical measurements of water content with an accuracy similar to that achievable through the wet chemistry method of Karl Fischer titration to be made. In addition, a non-destructive moisture analyser was obtained which utilises microwave technology and does not require the sample under test to be dried.

A number of other instrument types are in widespread use, but could not be investigated within this limited study. However, many of the findings of this work can inform approaches to valid measurement and traceability for a wider set of instruments.

2. MEASUREMENT PRINCIPLES AND ISSUES EXPERIENCED FOR SELECTED INSTRUMENTATION

2.1 MOISTURE MEASUREMENT PRINCIPLES

The physical principles utilised by the instruments are described below. The measurements variously address water content, or moisture content including other volatiles. Where the distinction is important, the term “water content” is used.

2.1.1 Gravimetric loss-on-drying analysis

Measurements of mass before and after a sample has been dried are used as a means of determining moisture content. This is expressed as a percentage of the initial mass of the sample :

$$\text{Moisture content “wet basis”} = \frac{m_w}{m_w + m_d} \times 100 \% \quad (1)$$

where: m_w = mass of water and m_d = mass of dry material. Mass loss on drying is widely used as a reference method for moisture content measurement, although protocols in published standard methods vary significantly for different applications, so this approach is far from providing a single universal standard.

Two methods to determine moisture content through gravimetric loss-on-drying analysis were acquired for the facility. The first is a laboratory based method providing the ability to measure sample masses using a high precision balance with a resolution of 10 µg before and after drying in a separate convection oven. The second, a portable “moisture analyser”, combines a lower resolution balance (1 mg) with an incorporated radiative heating element in a lid above the pan of the instrument (see Figure 1). The change in mass of a sample during drying is used to calculate and display real time values of moisture content.



Figure 1: Moisture analyser, balance with incorporated infrared heating element.
Source: Sartorius

2.1.2 Coulometric analysis of evolved vapour

The NPL facility incorporates an evolved vapour analyser for moisture. This utilises a phosphorous pentoxide humidity sensing cell which generates a current when it reacts with water vapour molecules in a gas stream. Water vapour is evolved from the sample through heating in the instruments internal oven, for which heating profiles can be defined. A dry gas stream passes over the sample which mixes with the evolved water vapour, carrying it to the sensing cell. The current output of the sensing cell is related through Faraday's law to the number of water vapour molecules reacted. The calculated mass of these water molecules is compared to the initial sample mass, measured using a precision balance prior to analysis, to calculate a percentage "water content" value for the sample under test.

This instrument is stated by the manufacturer to be able to provide an accuracy of water content measurement comparable to that achievable through the established wet-chemistry method of Karl-Fischer titration.

2.1.3 Microwave resonance analysis

A microwave moisture analyser is able to measure a shift in the peak frequency of microwave resonance in a cavity due to moisture in a sample inserted in the microwave field. This enables non-destructive measurements of moisture content to be made once a calibration relating frequency shift to moisture content has been established, relating frequency shift to moisture content for the material under test.

2.2 GOOD PRACTICE AND MEASUREMENT ISSUES

2.2.1 Sample handling good practice

Well known measurement issues concerning sample handling were encountered during the project and the established good practice followed is described below.

If subjected to environmental changes, the moisture content of materials tends to differ at the surface compared to that deeper into the bulk of the material due to exchanges of moisture with the surrounding environment in which the sample is stored. The humidity of air can be used to control the moisture content of materials and measurements of humidity (known as equilibrium relative humidity or water activity) above materials are also made by users as an alternative to measuring the moisture content of the material itself.

Sampling is a concern for all moisture measurement techniques. It is important to ensure that the sample measured is representative of the moisture content of the entire batch under analysis. Mixing or stirring of a bulk material is usually recommended before analysis to homogenize the material under test. It is good practice to analyse several samples from different parts of a bulk sample to better characterize the moisture content of the entire batch of material.

Certified reference materials (CRMs) can be purchased which have certified measured values in terms of either moisture or water content, and an associated uncertainty

assigned through repeated measurement of the same batch of material at several laboratories. CRMs are typically sealed within foil packaging and should generally be stored at low temperatures before use, to prevent water loss. Prior to opening the CRM packaging the user is instructed that the material must be left to equilibrate to the room temperature in the laboratory to avoid condensation forming on the material's surface and adding to the moisture content. The certified value of moisture or water content is only guaranteed by the manufacturer if the material is used immediately after opening the packaging. In use at NPL, all usual precautions were taken to minimise moisture uptake or loss due to the humidity in the laboratory, and the foil packaging was resealed using metallic tape when samples were not being removed for analysis.

2.2.2 Gravimetric loss-on-drying analysis measurement issues

When heating a sample, it must reach a temperature high enough to drive off all of the moisture held in the bulk of the sample, whilst not being so hot as to lead to charring and decomposition of the sample, which can result in additional mass loss. At NPL this temperature was determined in a case by case basis by using the coulometric vapour analysis instrument to investigate the amount of water released over a range of temperatures as described below in Section 2.2.3.

Mass loss through heating may be due to volatiles other than water being evaporated when a sample is heated, defining the resultant values of these techniques as measurements of "moisture content" rather than being water specific measurements. Volatiles other than water in materials that can account for mass loss during heating include fats, oils, alcohols and products of decomposition if a sample is overheated.

Uneven application of a sample to the disposable aluminium pans used with the moisture analyser will result in an uneven absorption of heat and not all the moisture present may be driven off. A high point in the level of the sample will bring this region physically closer to the heating element making the possibility of charring and sample decomposition more likely.

Tare measurements were made of changes in mass to the empty sample holders used and any mass loss observed was corrected for in moisture content calculations. The effects of convection due to hot samples being placed on balance pans were investigated and included as a factor in the uncertainty evaluation for these techniques.

2.2.3 Coulometric analysis of evolved vapour measurement issues

As the reaction of the sensing cell is water specific, this instrument can truly measure the "water content" of the sample. The oven's programmable heating profile allows step changes in temperature to be defined at which water in different states (surface, capillary and chemically bound water) will be evolved and can be observed as separate peaks in the current output (see Figure 2). The fractions of these water states can be resolved from the data using software provided by the manufacturer.

For each material measured, an investigation using temperature profiles with several step changes in temperature revealed the maximum temperature with no charring, duration of measurement required, and the fractions of the different water states present in the sample. Once this information was known a measurement temperature profile was defined which would rise to the maximum temperature and hold the oven at this



Figure 2: “Capillary water” fraction resolved from results of coulometric analysis of evolved vapour of polyethylene terephthalate (PET) sample.

temperature for the required duration to drive off all water and return the output current to the initial background level. Analysing a material in this way prior to gravimetric loss-on-drying measurements provided information about the maximum temperature required during heating to fully measure the water in all forms present in a sample.

Tare readings were made to assess the surface water given off by the nickel boats used to hold samples in the oven during analysis. The boats were all conditioned in the same manner before use, cleaned with isopropanol and baked at >150 °C for several hours before storage in a sealable container. This procedure achieved uniformity in the amount of surface water present on the boats such that the measured tare value could be subtracted from all future measurements using this temperature profile

This instrument operates with small sample sizes (typically much less than 1 g) and a managed level of heating targeted to release water at a controlled rate so as not to exceed the capacity of the sensor. The reactivity of the phosphorous pentoxide sensing cell is such that if there is too much water released into the gas stream at once it will reach the peak current output and not be able to react further, resulting in a plateau in the current output. In these instances further water vapour could flow past the sensing cell without being detected it and an underestimate of water content would result. For this reason it is essential to achieve a peak below the maximum current output of the cell to achieve accurate water content measurements. The duration of a measurement must also be long enough for the output current to return to the base level observed at the start of a measurement to ensure all of the water contained in the sample has been detected.

Reducing the flow rate of the carrier gas, and increasing the time taken between step changes in the temperature profile of the oven can improve measurement accuracy where saturation of the sensing cell is a risk.

Sodium tartrate dihydrate with a certified value of water content (nominally 1%) is used to calibrate the phosphorous pentoxide sensing cell periodically. A mean correction factor is calculated from several repeat measurements of the CRM which when applied corrects the instrument to read the water content value certified to within the stated uncertainty of the CRM.

If the determined correction factor drifts outside the manufacturers recommended range (0.8 to 1.2) then the sensing cell is removed and recoated with a chemical solution to reactivate the cell. If the base current reading is too high this can be due to insufficiently dry air supply, requiring reactivation of the desiccant by baking in an oven.

As a novel step, NPL adapted the gas supply to the instrument to use dry air from the laboratory compressed air supply (dew point $-50\text{ }^{\circ}\text{C}$) rather than ambient air. This improved the uniformity of the level of the instrument base current output, and extended the time between desiccant reactivations.

2.2.4 Microwave resonance analysis measurement issues

The instrument generates resonant microwaves in the sensor's cavity at a peak frequency which is subject to shift as a function of the moisture content of a sample inserted into the cavity. Each material type to be analysed requires a calibration which relates the shift in the observed microwave resonance frequency to the moisture content of the sample inserted into the cavity. Samples from a batch of each material to be measured are conditioned to a range of moisture contents using water baths, desiccators and salt solutions to provide calibration data prior to analysis. The samples are inserted into the cavity in purpose made plastic applicators for which the frequency shift resulting from the insertion of an empty applicator is first measured and subtracted as a background tare from future measurements.

Bulk samples to be measured should be of a large enough amount to fill the applicator so that the entire length of the resonant field in the cavity is perturbed by the introduction of the material.

Experimentally, NPL has used the instrument to analyse samples that do not fill the volume of the applicator. In this case, it is essential that any sample to be analysed can be repeatedly located in the same space within the cavity to ensure the same part of the resonant field is being perturbed with each measurement. To do this, sample holder inserts were made from a material that does not interfere with microwaves in the frequency range used. The zero offset for the empty applicator was determined with the sample holder insert in place. By this approach, it was possible to experimentally measure relatively small samples. This method was used for the work described in Section 3.1.3, to measure progressive changes in biodegradable polymer samples.

Calibration of this instrument is only valid when the reference measurand fully corresponds to the instrument measurand. For example, it may be unknown to the user

whether the microwave field interacts with other constituents in addition to water (ideally, the operating resonant frequency is tailored to avoid this). Conversely, classic gravimetric loss-on-drying reference values (in terms of total moisture content) will not be appropriate for calibrating an instrument which detects only water, or only that fraction of water in a particular state of chemical binding. This issue of specificity is a potential concern for calibration of all “indirect” measurements where the output is not intrinsically amount or mass of moisture or water, but some other parameter.

2.3 UNCERTAINTY ESTIMATES

2.3.1 Uncertainty overview

Example results of measurements of a wheat flour CRM using several methods are shown the graph in Figure 3, together with error bars representing provisional estimates of expanded uncertainty based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95%. Details of uncertainty estimates are discussed further below.

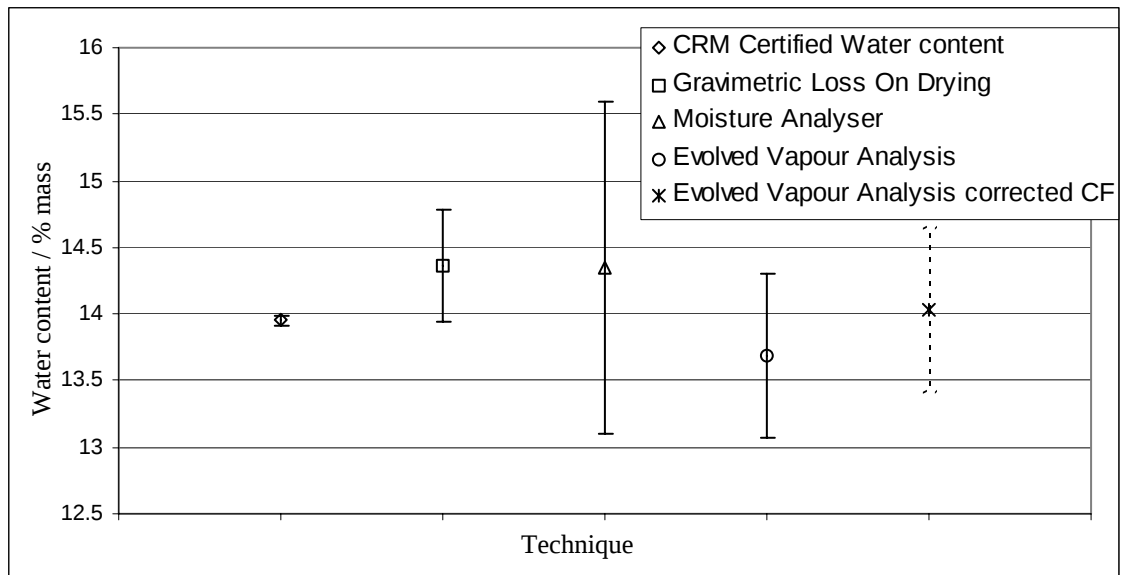


Figure 3: Results and associated uncertainties of moisture content measurement of Wheat Flour CRM samples using gravimetric and coulometric instruments.

When considering uncertainties that should apply for the selected measurement techniques there are contributions which are instrument dependent. There are also material dependent contributions which must be quantified for each material tested.

For this report a CRM consisting of wheat flour [1] was analysed by gravimetric loss on drying and evolved vapour coulometric techniques in the NPL moisture facility. An initial uncertainty evaluation was carried out for the specific case of this material. The mean values of 15 repeat measurements of moisture/water content by each instrument are displayed in Figure 3, together with the associated uncertainty estimated. The wheat flour CRM had a certified moisture content of $(13.95 \pm 0.04) \%$.

2.3.2 Uncertainty in loss-on-drying values

Uncertainty evaluation of the gravimetric loss-on-drying techniques took into account factors including balance calibration, drift, resolution and repeatability.

An important consideration for this method was the effect of convection around hot sample holders placed onto balance pans. This was investigated along with repeated measurements to determine the effect of water uptake to the sample dry mass once it had been placed on the balance pan.

A rise in mass reading over time was observed when a hot sample contained in a metal sample holder was placed on the balance pan. This mass rise was investigated through measurements of the mass rise of hot empty sample holders and analysis of the water content of the dried samples once the mass value had stabilised through the coulometric analysis of evolved vapour technique. A repeatable temperature effect due to hot sample holders being placed on the balance pan was quantified and a correction was applied. The measurements of water uptake over time were evaluated and an uncertainty contribution was included for the estimated mass change that occurred during transportation of the sample from the oven to the balance pan.

2.3.3 Uncertainty in evolved vapour analysis

For the measurements made using the coulometric analysis of evolved vapour technique the performance of the phosphorous pentoxide sensing cell was found to be the primary source of uncertainty.

The sensing cell's reactivity varies over time and as a result the value of the correction factor determined periodically will change. The magnitude of the shifts in correction factor measured between determinations was evaluated and included in the uncertainty evaluation.

The performance of the sensing cell is inherently dependent on the stability of the CRM used to determine the correction factor. The certified reference material used to determine the correction factor for the sensing cell performance had an associated uncertainty which propagates as an uncertainty in any measurements of water content made.

Three separate batches of the sodium tartrate dihydrate CRM were analysed which had been used to different degrees over the course of the project. By referring the resultant water content values to a freshly opened sample of the CRM, it was found that a jar that had been opened and used about 30 times was measured to have increased in water content by 0.025 %, and a batch that had been used about 60 times was measured to have increased in water content by 0.06 %. The measurements of water content made of the plain flour CRM through coulometric evolved vapour analysis initially seemed to be low compared to the certified value of the material. With the knowledge that the CRM used to determine the correction factor for the sensing cell was actually 0.025 % higher in water content than the certified value entered for correction factor determination, it was apparent that a correction should be applied to account for the sensing cell under-reading the amount of water evolved from the sample. Applying this correction resulted in an increase in the water content result as shown in Figure 3.

2.3.4 Uncertainty in microwave analyser

The microwave resonance instrument inherits uncertainties from the above methods which are used to provide water content reference values for its calibration. At this time, only an approximate uncertainty for this instrument has been estimated. Effects that will need to be more fully assessed in the future include: the repeatability of frequency shift when a sample is inserted, uniformity of the microwave field in the cavity, effect of sample positioning in the cavity and repeatability of the empty applicator tare.

2.3.5 Uncertainty summary

Broadly, the measurement results and estimated uncertainties were consistent with the certified value. The small differences in the results can be explained by the physical approaches utilised by each of the instruments to determine the moisture/water content of the sample. Also the composition of the sample (powder, grain, bulk material) and the uniformity of its distribution under the analyser can affect the results obtained.

2.4 RECOMMENDATIONS TO USERS OF MEASUREMENTS

Users of moisture content or water content measurements need to be aware of best practice and limitations of measurements and measurement traceability. It is recommended that:

- Users of moisture measurements should follow established good practices on sample handling and storage. Published standards, and instrument or CRM suppliers are valuable sources of guidance (but not the only sources).
- Measurement users should make use of appropriate certified reference materials in conjunction with other measurement traceability (e.g. to mass standards) to underpin measurements.
- Where possible, measurement comparisons between instruments, or checks using stable (reference) materials, or simple repetition can increase confidence in measurement procedures and results, or reveal discrepancies if present.
- Measurement users should assign realistic uncertainties to moisture measurements, as far as these can be estimated. Total uncertainty tends to be significantly greater than individual components such as repeatability quoted in instrument datasheets.
- Measurement users should be aware of uncertainty incurred in transfer of traceability down any chain of calibrations. For example drift of reference values can be significant in many cases, and is not included in the uncertainty given on calibration certificates. This needs to be considered for values derived from moisture CRMs, depending on the conditions of their use.

3. FURTHER PROJECT ACHIEVEMENTS

3.1 PRACTICAL MEASUREMENTS

3.1.1 Measurements of industrial powders

Trial measurements of moisture content were offered to industrial partners involved with powders processing through the “PowdermatriX” network, part of the Materials KTN. Four parties took up the offer of trial measurements and sent powders into NPL for analysis. Powders consisting of a variety of materials from polymers to titanium were sent in for analysis. The results benefited the companies through characterisation of the moisture content of samples taken from different stages of their industrial processes. Information about drying temperatures and durations to reach required moisture levels was also evaluated in order to advise on making drying processes more efficient.

3.1.2 Determination of repeatability data for ISO-62 standard

The procedure described in ISO 62 [2] was followed to periodically determine the water content absorbed by square-shaped test specimens of Nylon, PMMA, ABS and HDPE polymers during immersion in water at 23 °C. At least 15 nominally identical specimens of each polymer type were tested in order to produce repeatability data which was considered at a recent meeting of the standards committee. The findings are to be published so that the next revision of the ISO 62 standard, due to be published next year, can make reference to the results of this work.

3.1.3 Non-destructive moisture measurement of biodegradable polymers for medical implants

Investigative work was completed in collaboration with NPL colleagues to make measurements of the moisture content of samples made from a biodegradable polymeric material used for medical implants. The polymer is used to produce screws that are used in surgical procedures to attach tendons or ligaments to bone tissue. During the healing process, the polymer is designed to degrade and be absorbed into the body. The work was a step towards characterising the degradation process, as it identified a non-destructive moisture measurement technique that can be correlated with the degradation of the component. An abstract has been submitted to the TEMPMEKO & ISHM 2010 conference for presentation and publication in the conference journal.

3.1.4 Investigation into the use of surface acoustic wave spectroscopy to measure moisture content of coatings

A feasibility study into the use of surface acoustic wave spectroscopy (SAWS) to measure the moisture levels in coatings was completed. The aim was to identify candidate hygroscopic substances which could be prepared in coating form and to make measurements using an adapted surface acoustic wave technique on moisture-conditioned coated substrates.

The selected coatings were detectable using surface acoustic wave spectroscopy, demonstrating the expected dispersion effect on the surface acoustic waves. There was evidence that a shift in dispersion fit gradient and intercept occurred. This showed some

correlation with changes in coating moisture content, which was controlled and varied by adjusting the surrounding air humidity.

This investigative work, however, is not yet at a publishable level; further work would be required to definitively prove the concept.

3.2 KNOWLEDGE TRANSFER ACTIVITY

In February 2009 NPL held a TMAN event entitled “Measurement & Control of Moisture in Materials” where speakers ranged from academic researchers to instrument manufacturers and end-users. The event featured presentations from, GSK, University of Surrey, Rotronic UK, NDC Infrared Engineering, and several NPL speakers. Subjects included: industrial drying; moisture in polymer composites and adhesives; magnetic resonance imaging; water activity; terahertz spectroscopy; and NPL’s emerging capability for moisture measurements. 33 delegates took part and four companies exhibited moisture instruments. Some of the presentations are accessible at: <http://www.npl.co.uk/networks-clubs/tman/events/4-feb-09-measurement-control-of-moisture-in-materials> .

NPL initiated EURAMET Project 1065 “Survey & strategic planning in the field of measurement of moisture in materials” as an opportunity to share knowledge and coordinate NMI activities strategically where possible. Participants from NMIs of Denmark, Romania, France, Finland, Egypt and Germany shared information about their activities in moisture measurement. Current NMI areas of action in this field vary greatly - from publication of technical notes (France), to calibration of some moisture meters (Egypt), to pattern approval of grain moisture instruments (Germany) to moisture measurement services and research studies (e.g. Denmark, Finland). Drivers for the work varied somewhat according to national industries, spanning: building materials; oil and gas; alternative fuels; wood; paper; food; agriculture; and high-value processing (e.g. polymers, pharmaceuticals). NMI development of moisture calibration methods or reference materials was limited, but several participants voiced a need for this work to be done. Participants are considering opportunities for secondments or other linked work in future.

NPL has submitted the following abstracts to the TEMPMEKO & ISHM 2010 conference to be held in May 2010 in Slovenia :

- An oral presentation and paper titled “Non-destructive moisture measurement of biodegradable polymers for medical implants” detailing the work described in section 3.1.3
- A poster presentation titled “A facility for measuring moisture content of materials” highlighting the work completed in the UP10 project and the facilities now available at NPL.

Other publications will be prepared, based on the work so far completed.

Throughout the course of the project NPL received enquiries from interested parties about measurement of the moisture content in materials ranging from plastics to soil to biofuels. For example, we were asked about the feasibility of non-destructively

measuring the moisture content of willow used in the manufacture of cricket bats. In some cases it was possible to support users by giving technical advice, even when measurements at NPL were not pursued.

4. PROPOSALS FOR FUTURE WORK

Recommendations for further work include the following:

- It is desirable for UK industry to have ongoing access to expert independent measurements of moisture content provided as a service in a laboratory, or at user locations where feasible. Particular areas of interest are: the research and development of new materials, and materials processing, and biofuels.
- Users of moisture measurements would benefit from access to impartial specialist advice on matters such as calibration, measurement good practice, and relationship between material moisture content and air humidity.
- Developments should be sought towards identifying further moisture reference materials for wider applicability. Possible improvements beyond the state of the art might include:
 - CRMs that could be made available in larger sample sizes than currently
 - Material-specific CRMs of wider variety than available now
 - CRMs for different configurations of instruments, especially those using physical rather than chemical sensing principles (microwave, RF, conductance, near infrared reflectance, others) for which CRMs are particularly limited.
 - CRMs suitable for use across a variety of techniques and industries (addressing either water content or broader moisture content) usable with existing published standard loss-on-drying methods.
 - Reference materials usable for real-time process moisture measurements
- A study into the relationship between moisture content and equilibrium relative humidity (water activity) would incorporate existing expertise in humidity measurement resulting in practical measurement data for selected materials.
- Increase user awareness and understanding of uncertainty in moisture measurements.
- Where appropriate, suppliers of instruments for moisture measurements should be engaged in two-way knowledge sharing, and as a channel of dissemination to instrument users
- Other centres of moisture measurement expertise beyond NPL, such as LGC, relevant trade associations, local trading standards laboratories, universities, and others should also be engaged in knowledge sharing and dissemination.
- UK experts should have opportunity to input to standards-making bodies such as BSI and OIML, where relevant to moisture measurement. Any standardisation would need to accommodate application-specific or material-specific approaches to moisture measurement.

- Established and newly-developing moisture facilities at NMIs across Europe and worldwide should be used collaboratively to maximise impact of the knowledge and services available.

NPL hopes to use the established moisture facility to promote more consistent and traceable physical measurements of moisture made within the UK. The moisture measurement capability is available to support UK industry and NPL projects, through measurement services and consultancies.

Through consultation with users and instrument companies, NPL will continue to seek ways to improve measurement traceability for moisture measurements. This could be through development and characterisation of potential new reference materials, aiming for wide ranging applicability across different technologies, end-uses, sample sizes and configurations.

Further work will be proposed as part of formulation of the NMS Programme for Engineering and Flow Metrology for 2010 onwards.

5. REFERENCES

[1] EUR 16478 EN : CRM 563 Certification of Properties of Common Wheat Flour Reference Material ISSN 1018-5593

[2] BS EN ISO 62:1999 Plastics – Determination of water absorption