Kett

SCIENCE OF SENSING

Learn the Six Methods For Determining Moisture

ADVANTAGES, DEFICIENCIES AND WHO USES EACH METHOD

CONTENTS

1. INTRODUCTION

With three-quarters of the earth covered with water, almost everything we touch or eat has some water content. The accurate measurement of water content is very important, as it affects all aspects of a business and it's supply chain. As discussed in our previous ebook "A Guide To Accurate and Reliable Moisture Measurement", the proper (or improper) utilization of moisture meters to optimize water can be the difference between profitability and failure for a business.

This ebook, the **6 Methods For Determining Moisture** is for anyone interested in pursuing the goal of accurate moisture measurement, including: quality control, quality assurance, production management, design/build engineers, executive management and of course anyone wanting to learn more about this far reaching topic. The purpose of this ebook is to provide insight into the various major moisture measurement technologies and to help you identify which is the right type of instrument for your needs.

Expect to learn the six major methods of moisture measurement, the positive aspects of each, as well as the drawbacks. If one method was a clear "winner" we'd only need those types of instruments, but, as you'll soon learn there is no "perfect" technology. However, there may be a "perfect" technology for your application. I hope you'll find the book helpful and look forward to your feedback.

2. PRIMARY VS. SECONDARY TEST METHODS

Before we start on the actual moisture meter categories, we need to briefly explain basic measurement instrumentation.

There are two major categories of test instrumentation – primary methods and secondary methods.

The Primary Measurement Method - Explained

A primary method is a test method that can test "anything" without calibration. As an example, when measuring speed, a long tape measure and a stopwatch can test anything – car, bike, motorcycle, runner, hare, tortoise and provide its speed. Obviously you'd need a longer tape for the car and motorcycle but the measurement principles are the same. Set a fixed distance and measure the time the moving object takes to cover the distance. The travel time divided by the distance gives the speed.

The Secondary Measurement Method - Explained

A secondary test method is an instrument that is product specific, which must be calibrated for the specific requirements before it can be used. Back to the speed measurement, a speedometer is an example of a secondary measurement. Before it can provide an accurate speed, it must be programmed with the diameter of the tire. It then counts the number of rotations of the wheel, multiplies that by the circumference of the wheel (based on the wheel diameter), divides by a unit of time and displays the speed.

While a speedometer takes some initial work to "calibrate", in the end, most people would agree it is a much easier measurement tool to use instead of the stopwatch and tape measure. But, if you're going to be measuring the speed of items without tires (say the tortoise and hare) a speedometer won't work. Also, if you don't know the size of the tire, or the tires sizes are changing each day, and maybe never being the same diameter, you'd need to stick with the tape measure as it wouldn't make sense to calibrate for just the one test.

3. PRIMARY METHODS FOR MEASURING MOISTURE

Who Needs to Use a Primary Moisture Meter Method

Certain applications are better suited for primary moisture meter technology versus secondary moisture meter methods. Similar to the tape measure/speedometer comparison described above, if the moisture measurement application requires that different products be tested each day, a primary method must be used. Examples are in an independent test lab, a crime scene lab, customs office or within a pure product research facility. Since samples aren't available for calibration and may never be seen again after the testing is completed, it doesn't make sense to calibrate a moisture meter to perform a secondary test.

One exception to this guideline would be where relative moisture values (versus real moisture content) between samples are acceptable. An example might be an online process where the sample moisture content substantially changes as soon as it is gathered, making a true offline measurement infeasible. Another exception occurs where a huge number of samples need to be tested (like a very large soil testing project). In this case, it may pay to calibrate a secondary moisture measurement method with several samples and then perform the remainder of the tests with the secondary method. Finally, another exception is seen where the samples are so precious that saving even a few samples from alteration is cost effective when offset with the time needed to calibrate a secondary method. Some pharmaceutical and cosmetic/personal care measurement applications fall into this category.

Let's explore the two major methods of primary moisture measurement.

KARL FISCHER MOISTURE METER METHOD (KF)

Explanation

Originally invented by the chemist whose name it takes, the Karl Fischer Method (KF) of moisture measurement is based on chemical reactions. The product to be tested is combined in some fashion with chemical reagents. A chemical reaction occurs where the water is separated chemically from the remainder of the sample. The water is then moved to another cell where it is measured. That measurement is compared with the initial mass or volume of the sample and the moisture content is calculated. Karl Fischer tests can be very accurate, testing to the Parts Per Million (PPM) level.

There are two major categories of KF systems or methods: volumetric and coulometric. The major difference is that the reagent chemicals are directly added in a volumetric system while the reaction is created electrochemically in a coulometric system. Volumetric systems measure the amount of Iodine used in the reaction and can then automatically calculate the water molecules attached. Coulometric systems measure the amount of current generated during the titration (Coulombs) and convert that value into water content. Volumetric systems can measure down from ppm to 100% but require a certain volume of water. The coulometric method can measure from 10 micrograms to 10 milligrams of water (low water samples).

However there are some drawbacks. First, the test is destructive, meaning the sample is altered and can't be reused or reintroduced into the main product sample or batch. This can be an issue where the product is very rare and/or expensive. A Karl Fischer moisture test takes some time to complete. The instrument must break down the sample into a liquid and then separate the water molecules from the remainder of the sample. In some cases one test can take an hour or more to complete. In many cases, the solids react with the KF reagents or are insoluble. In these cases, the method utilizes a two-step process. First, the sample is heated and the moisture driven into the solution. Then the solution goes through the KF process to calculate the moisture content. It is important to consider the ambient environment. While the systems are sealed, a small amount of the localized atmosphere gets into the system. In humid environments this can dramatically affect the measurement accuracy.

In addition, the test takes some degree of expertise. While auto-titrators now substantially automate the process, it still requires handling of chemicals, vials, samples, and the cleaning of small parts and pieces. This may raise health and welfare safety issues. The Karl Fischer technology also takes an initial degree of technical expertise to ensure that the chemical reagents are properly selected, the moisture test is properly configured, and the procedure defined for properly dealing with end-products. In some cases, the resulting waste product may require special handling and costly and/or time-consuming documentation for disposal.

Examples of KF technology

- Manual Titrator.
- Auto-Sampling Titrator (or auto-titrator).
- Volumetric Titrator.
- Coulometric Titrator.

KF Advantages

- It is a primary method and doesn't need calibration by product (within reason).
- Can measure moisture content to a very high degree of accuracy.
- Works very well when testing liquids.
- Can measure hydrated molecules.
- Can test very small samples.

KF Deficiencies

- Takes time – may be longer than a loss on drying test and certainly longer than a secondary method.
- Blank tests are generally required between every sample tested.
- Chemical reagents are used to perform the test – they are expensive to purchase and to dispose.
- Will not work with all products (additional chemical reactions may take place and skew the results).
- Measures hydrated molecules (may not be representative of true "water").
- Samples are destroyed or altered.

Pricing

Karl Fischer moisture measurement systems have come down in price in recent years. Models are available for approximately $5,000 (USD) but, with accessories and supplies, $7,000-$10,000 is a good range to expect. When an auto-handler is added, overall costs can go to $20,000. Depending on the products to be tested for moisture content, heaters and other "prep" steps may need to be added.

Who Uses the KF Method

Pharmaceutical companies are large consumers of the KF method. Given the variety of chemicals in their sample, the critical nature of the measurement and regulatory documentation necessary for all aspects of production and measurement, the KF moisture measurement technology is the first method considered. Another standard use for the KF technology is for the measurement of liquid samples. Since the sample doesn't need to be broken down from a solid to a liquid (by dissolution) the test is faster and can compete with loss-on-drying systems for throughput.

- Pharmaceuticals
- Chemicals
- Flavoring
- Cosmetics
- Contract Test Laboratories

LOSS ON DRYING MOISTURE METER METHOD (LOD)

Explanation

The original primary moisture measurement method was Loss On Drying (LOD). In an LOD test, the sample is weighed, dried, and weighed again. The difference in the two weights (Loss on Drying) is then compared with either the original weight (Wet-base test) or final weight (Dry-base test) and the moisture content calculated. Tests can be manually conducted (weigh, oven dry, weigh) or automated (integrated weight and heating unit) with systems called Moisture Determination Balances. Depending on the balance and heating mechanism, a wide array of precision and accuracy is available. Today there are even micro-moisture analyzers, using microbalances that can provide moisture measurement to the PPM level, consistent with the limits of KF testing.

Drawbacks of LOD test method are that it is destructive, meaning the sample is altered by the heating. In addition, it may be time-consuming with some tests taking 30 minutes or more to complete. Further, the test makes the assumption that all weight loss is due to water. In cases where substantial other volatiles (organics) are also available, this may not be the truth. Therefore, the results will overstate the moisture content and the test temperatures must be kept low to avoid excessive loss of these “non-water” based components. Lowering the temperature increases the test time. Finally, the samples are dried with people involved. Where there is heat involved, safety and labor costs may become a concern.

Examples of LOD Moisture Measurement Technology

- Forced air ovens.
- Convection ovens.
- Vacuum ovens.
- Infrared moisture balances.
- Microwave (drying) ovens.

LOD Advantages

- It is a primary method (does not require calibration).
- Can measure high levels of moisture.
- Moisture balances are cheaper than more sophisticated instruments.

LOD Deficiencies

- All volatiles are evaporated, causing improper moisture content calculations.
- Operator error can contribute to inaccurate readings.
- Air ovens are large and occupy a significant amount of space.
- Air ovens are generally very expensive both to purchase and for the energy needed for an ongoing operation.
- Cannot easily test liquids.
- Samples are destroyed or altered.
- Tests take some time to conduct.

Pricing

Good entry-level moisture balances start at around $2,000 and depending on features, capacities, and precision levels (mostly balance dependent) can run to $5,000-$7,000. Large ovens can run from $5,000 to $15,000.

Who Uses LOD Method

The LOD moisture measurement method is generally used in labs for monitoring the quality of products taken from a production line. Air Ovens used to be the standard but in the past decade, automated moisture balances have slowly been taking over in this capacity. Products that do not have other volatiles are good with this method. Minerals, metal products and many plastics fit this category. They can be heated to relatively high temperatures to obtain quick, accurate measurements. Many food companies use the LOD method since it is generally faster than the KF and doesn't require the same level of expertise or the moisture measurement precision offered by the KF method. Environmental test labs use the LOD method for their soil samples. In a large oven they can simultaneously test many samples, dramatically reducing the test time/sample.

- Food companies
- Pharmaceutical companies
- Pulp and paper
- Chemical companies
- Contract test laboratories

Summary – Primary Moisture Measurement Methods

While both primary methods work well under controlled situations, they are far from ideal. While the lack of need for calibration is one of their strengths, chemical reagent selection (in the case of the KF) and temperature settings (in the case of the LOD) do need to be determined before specific tests can be conducted. Destroying (or altering) the sample may cause issues. Finally, the time needed to complete these moisture tests may be too long to help optimize a manufacturing process. Instrument designers have created other moisture meter test methods to address these shortcomings. Remember though, all of the other methods are "secondary" meaning somebody, at some point in time, has to calibrate the instrument to provide "true" moisture. Be wary of anyone that tells you otherwise, what they are saying just isn't true.

4. SECONDARY METHODS FOR MEASURING MOISTURE

The major secondary methods for measuring moisture include electrical, microwave, nuclear and NIR absorbance Additional methods that are not as frequently used are hydrometry, refractometry, freezing point and GCMS.

Who Needs To Use Secondary Moisture Meter Method?

Just as there are certain applications that lend themselves to using primary moisture meters, there are other applications where a secondary moisture measurement method would be preferable.

As mentioned, if test time is crucial, an instant moisture reading made by a secondary measurement technology is required. While there are some very unique (and expensive) automated samplers for process line measurements, generally if an online or inline measurement is required, a secondary method is used. Also, if destroying or altering the sample is a problem, a non-destructive secondary moisture meter is needed.

The location of the test may also dictate that a secondary method be used. If the moisture measurement needs to be made in the field (think of a harvest or the measurement of live trees) a secondary method is suggested. An industrial measurement example would be measuring near a process line where having the heat generated by the LOD method or the chemicals needed for the KF would cause a safety issue.

The level of expertise of the staff needed to conduct the test may also be a consideration. It's a lot simpler to simply point an instrument at the sample and read the moisture content than it is to use a KF (and to a lesser degree a moisture balance or oven).

Finally, cost and test accuracy may lead to selection of a secondary moisture meter technology. Some professional grade moisture meters are available under $1,000 and still provide between 0.3 - 0.5% accuracy (when compared with a KF/LOD). This type of performance may be more than adequate for the needs and budget of the measurement application.

Let's explore the four major categories of secondary moisture measurement.

ELECTRICAL MOISTURE METER METHOD

Explanation

There are numerous ways to use electricity to measure moisture. These include capacitance, conductance, radio frequency (RF). However, they all rely on the dielectric principle. The dielectric constant of a material is proportional to the capacitance of the material and is a measure of its specific polarization or electric dipole moment per unit volume. For most common solid materials, the dielectric constant ranges from 2 to 4. Water, however, has a much higher dielectric constant than these materials (77 - 84), varying slightly with temperatures above 0oC. With this large variance, the water content of the solid can be calculated by measuring the dielectric constant of the solid.

When looking at capacitance, the capacitance of the solid increases with an increase in the number of water molecules per unit volume of the solid. Probes can be affected by salt concentrations. Dielectric and capacitance monitors measure free water molecules.

Examples of Electrical Moisture Measurement Technology

- Capacitance moisture meters.
- Conductance moisture meters.
- Resistance moisture meters.
- Radio frequency moisture meters.

Electrical Advantages

- Inexpensive
- Low power – may use batteries
- Easy to use
- Portable

Electrical Deficiencies

- These devices saturate at approximately 30-40% water content.
- They may have problems accurately measuring moisture below 4-6%, depending on the sample.
- The amount of moisture measured is highly dependent on the contact the probe makes with the product.
- These devices can only achieve 0.5% accuracy in best-case situations.
- Differences in sample density affect the measurement.
- Differences in temperature affect the measurement.

Pricing

While there are exceptions, electrical moisture meters are generally the lowest price category of the six moisture measurement technologies. Because of their low energy requirements, they can be portable and battery-powered, simplifying instrument design and usability. Professional grade instruments start in the $500 range and can run into several thousand dollars for specialized probes and online systems. Some low cost instruments are available from $100 but they may be lacking the instrument design, construction and features needed for long-term, accurate, professional use.

Who Uses Electrical Method

Electrical methods are used where instant measurement is needed, contact with the product is acceptable, top accuracy is not needed and cost is a key concern. In addition, the ability to have small battery powered portables allows electrical methods to be used in many field applications. They are typically sold to agricultural industries and wood manufacturers with farmers and wood producers being the primary users of the electrical devices. This is due to the ease of use and the low cost of these machines. Grain producers often use these devices as well, but recent trends have shown that they are heading toward the more sophisticated moisture meters.

- Grain and seed
- Other agricultural applications
- Wood
- Flooring
- Concrete

MICROWAVE MOISTURE METER METHOD (MW)

Explanation

Microwave is another measurement technology that takes advantage of the dramatic differences in the dielectric constant of water versus solids. Microwave energy is emitted from the instrument and passed through the sample. Some of the energy is absorbed (signal attenuation) and the signal may have a velocity change (phase shift), these changes are measured by the detector. Based on a product calibration, the microwave energy changes are converted into a moisture content measurement. Samples may be static desktop samples or moving online/inline samples.

Generally, at least 20 samples are needed for calibration. In some cases the instrument is then bias-adjusted with a single point calibration at the customer facility to adjust for local effects (in particular, interference from the physical process line). Depending on the implementation, measurements may be refreshed every couple seconds to provide a continuous control point.

One advantage of the Microwave method (MW) is the fact that it generally is transmitted completely through the samples. For products that have multiple layers (think plywood) that may have very different moisture levels, this capability is needed. However, MW moisture meters are density dependent, so some sort of compensation must be used if the product sample or process has variable density. Back to the plywood example, imagine if the plywood was twice as thick. To keep it simple, the meter would see twice as many water molecules and the moisture content displayed would be doubled.

Examples of Microwave Moisture Measurement Technology

- Desktop analyzer
- Online analyzer
- Inline analyzer

Microwave Advantages

- Test is instantaneous, non-contact, non-destructive.
- Moisture content measurement is representative of the entire product and is not just a measurement of surface moisture.

Microwave Deficiencies

- Tests are density dependent – they generally use a density compensation unit to compensate for this, which means the overall unit is larger and more expensive.
- Must be calibrated.
- At times, can't be used on frozen products – ice creates an unstable measurement process.
- Must be temperature compensated.
- Hard to conduct a field or an online system trial – generally must have a license and certified specialists on site during the test.

Pricing

Pricing for a non-destructive microwave moisture meter is $21,000 -$40,000 for the instrument. If the system is to be mounted on a process line where the product is falling (chute or gravity feed), add an additional $11,000 - $17,000 for the stainless sample port required for measurement. In addition, remember that some sort of density compensation device is generally needed (like a belt-weigher).

Who Uses Microwave Methods

Generally these systems are used in applications where instant measurement is needed “through” a sample since moisture distribution throughout the sample is not consistent. This includes online applications where environmental factors (rain, snow, sun) may affect the product as well as “layer” products like plywood or filled food products.

- Mineral applications
- Wood chips
- Frozen foods
- Packaged goods
- Coated products
- Locations where bulk and depth are a concern and surface moisture is not related to total moisture (plywood as an example)

NUCLEAR MOISTURE METER METHOD (NUC)

Explanation

In the Nuclear Moisture Meter (NUC) technology, energy is radiated into (or through) the sample and the amount of energy absorbed by the sample measured. Beta radiation (neutrons) is used for moisture and sometimes Gamma radiation is used to simultaneously measure sample density. The relationship between absorbed energy (high energy or "fast" neutrons) and moisture content is then calculated to create a calibration curve. Once calibrated for a specific product, this method provides instant, non-contact, non-destructive moisture measurement. Generally 10-20 samples are needed for a valid calibration. However the calibration can be faulty if other hydrogen atoms are present (other than H20). From the description it's apparent that the measurement principles and advantages are similar to the microwave moisture measurement technology.

Given the inherent additional safety concerns of the nuclear sources needed, why would this be selected over the MW technology? NUC meters provide a higher usable energy source. This is important in two instances. One is where the sample is very thick or dense (imagine a moving belt containing dense mineral or soil samples). The other example where this signal might be an advantage is on a single sheet web product, especially one that had multiple layers of different products. The limited product seen by the meter (since the product is thin) requires maximum sensitivity to see differences in moisture content.

Examples of Nuclear Moisture Measurement Technology

- Online moisture meter
- Portable moisture meter
- Transmission method
- Backscatter method

Nuclear Advantages

- Test is instantaneous, non-contact, non-destructive.
- Moisture content measurement is representative of the entire product and is not just a measurement of surface moisture.

Nuclear Deficiencies

- Nuclear sources are needed – may require special licensing, registration and on-site specialists.
- Must be calibrated.
- Hard to conduct a field for an online system trial.
- At times may only provide a relative value, requiring two instruments to be used and the changes monitored to actually be able to control a process.
- Bias and/or offsets may be needed for accurate measurement (based on other hydrogen atoms present in the sample).
- Safety is a key concern.

Pricing

As with most moisture test methods prices have of NUC systems have been reduced in recent years. However, given the complexity of handling (and protecting) the sources and radiation, “budget” systems are not in the forseeable future. Generally, these systems start over $100,000 and can be upwards of $250,000 when installed with a scanning frame (traverse) for control of a web-based process.

Who Uses Nuclear Moisture Measurement Method

While very specialized, some applications demand a nuclear meter. As previously mentioned, some mineral process applications require the power and some web-based processes require the precision a NUC provides.

- Pulp and paper applications
- Mineral processing

NEAR-INFRARED MOISTURE METER METHOD (NIR)

Explanation

Near-infrared (NIR) moisture meters utilize a measurement principle that is completely different from the conventional methods. Near infrared measurement uses reflectance & absorbance principles for calculating the moisture content of an item. This meter bounces a beam of light off the product (in some cases transmits the light through the sample). The light is filtered to a wavelength (or multiple wavelengths) that excite the moisture molecules. The higher the moisture content, the higher the amount of light absorbed. The instrument measures the light reflected back and an algorithm determines the light absorbed by the sample. As with the other 'secondary' methods, a calibration is initially determined by the relationship between absorbed light and moisture content. Generally 7-10 samples are needed for a valid calibration.

The major drawback of NIR moisture meters is the inability (in many situations) to measure through the entire product. While some NIR moisture meters are transmittance meters, most are reflectance configurations. The surface issue can be addressed because there is typically a relationship between the middle of the product and the outside. If this is the case, NIR can accurately detect the moisture on the interior of a product. An example where this would not work is a coated candy product. The NIR analyzer would measure the coating moisture but not the candy inside. The candy would need to be broken, chopped, or ground to get an accurate assessment of total moisture content.

Examples of NIR Moisture Measurement Technology

- Portable handheld moisture meter.
- Desktop moisture meter.
- Online/inline moisture meter.

NIR Advantages

- Results are instantaneous.
- The test is non-contact and non-destructive.
- Can be used on almost any liquid or solid.
- Portable, battery-powered units are possible along with online/inline and desktop form factors
- Can measure surface moisture to help with optimizing packaging, curing, drying, etc.
- Can be used with other wavelengths to measure multiple organic concentrations in addition to moisture (fat/oil, protein, sugar, fiber, etc).

NIR Deficiencies

- Needs to be initially calibrated (generally against a primary method).
- Only a surface measurement of moisture. To work properly, there must be a relationship between the surface moisture and total moisture of the product.

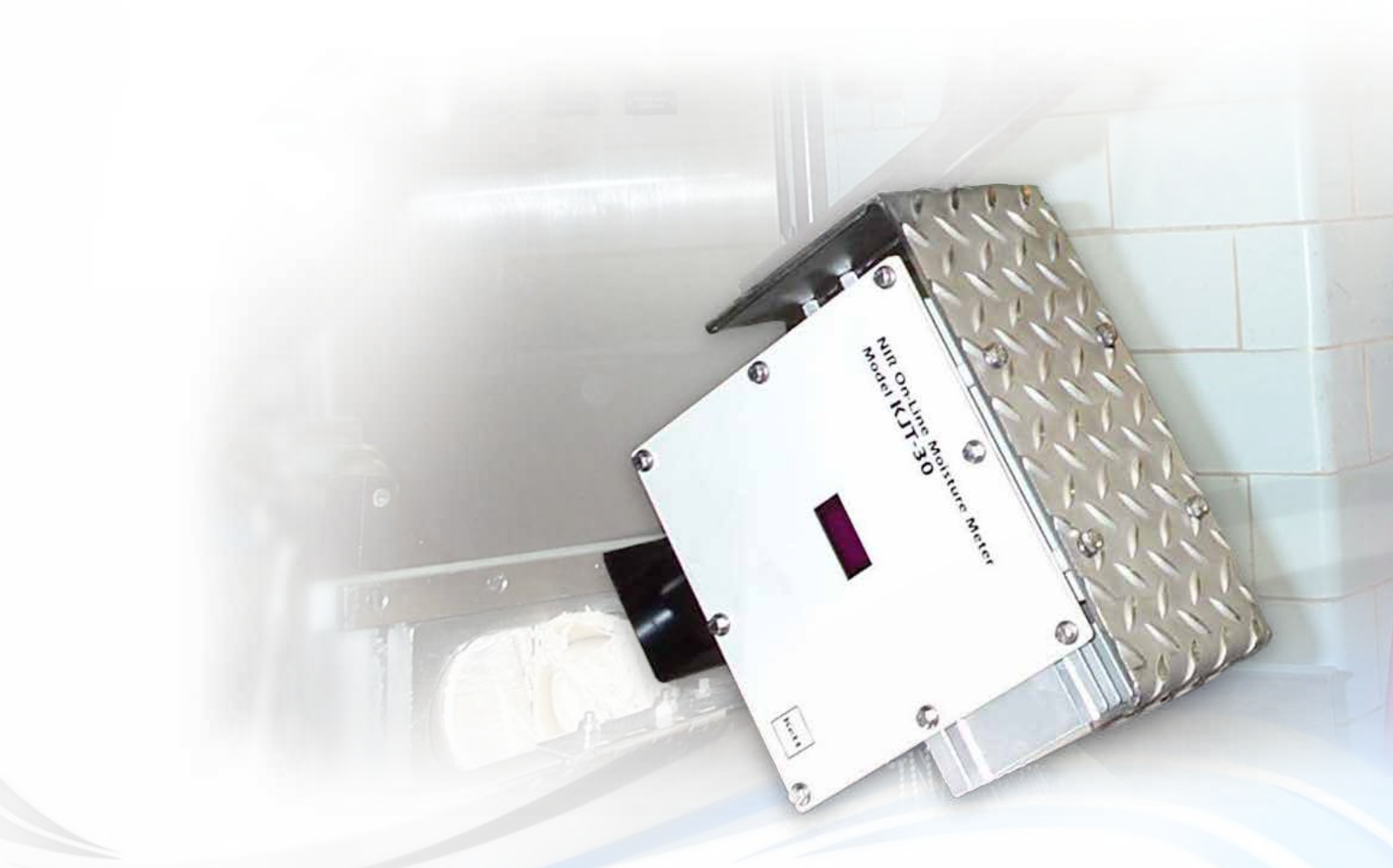
Pricing

NIR moisture meters run from about $10,000 to upwards of $40,000 per sensor. Configurations can be portable, desktop and inline/online.

Who Uses NIR Method

NIR applications are wide and varied. The NIR method of moisture measurement was originally developed by the US Department of Agriculture (USDA) for rapid analysis of foodstuff. Food manufacturers, processors and bulk food companies are large users of NIR moisture and composition analyzers. The tobacco industry has been a traditional large user of this method. The NIR method has started to dominate both the pulp and paper industries and pharmaceutical industries.

- Food and grain processors
- Tobacco
- Pharmaceutical
- Pulp and paper
- Minerals
- Personal care products
- Chemicals
- Textile



CONCLUSION

As we've discussed, there are a wide array of moisture measurement technologies. Each has advantages and disadvantages and when combined with unique implementations by instrument manufacturers, the selection can be overwhelming.

We hope that this ebook can act as a roadmap to help reduce your options to choosing the "best" technology and meter available, even if it's not perfect, for your unique needs.

Remember to review your needs first, determine what you must have and then create the "it would be nice to have" list. Then look through this manual to see which methods address the majority of your requirements.

ABOUT THE AUTHOR

John Bogart is the CEO and managing director of Kett US, a worldwide manufacturer of test instrumentation. John has been with Kett for over 20 years. He has held a variety of positions, including Director of Sales, Manager of Technical Services, and Domestic Product Manager. Prior to joining Kett, John held numerous sales, marketing, and engineering positions with IBM.

John received a Master of Management degree, with honors, from Northwestern University Kellogg School of Management, and is a graduate, Summa Cum Laude with Distinction from The Ohio State University, department of Engineering.

John enjoys his family, cycling, and sailing in Southern California.

ABOUT KETT

Kett helps their clients by immediately optimizing their production efficiency, improving consistent product quality and increasing profitability.

In 1946 four engineers had a vision to design and manufacture portable handheld moisture analyzers. After the successful introduction of a wood moisture meter and the Riceter, which is still the standard for portable rice moisture testing today, Kett expanded into Coating Thickness Gauges.

Today, Kett helps customers immediately optimize production efficiency, achieve consistent product quality and increase profits. Offering over 200 instruments, they focus on moisture and organic composition analysis, coating thickness measurement, friction, wear, peel, adhesion and other surface property analyses, rice quality instrumentation and other test instruments for the grain and seed marketplace.

Upgrading your test instrumentation to a Kett quality product will provide you with instant improvement in product quality, reducing waste and optimal energy usage in production.

NEXT STEPS

- I hope you enjoyed this ebook and found the information helpful to you and your company. Comments and suggestions for updates may be sent directly to John at: **jbogart@kett.com.**
- If you have an active interest in moisture (or organic composition – fat, oil, protein, sugar, etc.) measurement we'd love to answer your questions and help in any way.
  Please use our FAQ Forum.
- Our first ebook discusses the reasons moisture measurement is so important, and why updating to current technology is not only cost effective but is generally immediately cash-positive. If you haven't read that book you can download that here – **A Guide To Accurate And Reliable Moisture Measurement.**
- If you'd like to learn more about Kett and measurement instrumentation, please subscribe to **our blog**, join us on **LinkedIn**, **Facebook** and **Twitter**.
- In addition, you may wish how to learn how Kett can make acquisition of updated instruments simple, through our unique **rent-to-own** and **performance guarantee**.
- Brochures on Kett moisture measurement instruments can be found at:
  www.kett.com/freedownloads.aspx
- Finally, if you have a good idea of what you need, our applications engineers only need a few minutes of your time to confirm your requirements and suggest solutions from our wide array of moisture measurement instrumentation, whether a handheld portable, desktop, or online/inline solution is desired. Schedule this quick, **free session here**.

Whatever your interest level, we appreciate your consideration of our company and products.

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RESOURCES

For more detailed descriptions of the various moisture measurement technologies please see:

Karl Fisher	**http://www.who.int/whopes/quality/en/methodm7.pdf**
Loss On Drying	**http://www.astm.org/Standards/E1868.htm**
Electrical Methods	**http://www.s2is.org/Issues/v2/n2/papers/paper8.pdf**
Microwave	**http://naldc.nal.usda.gov/download/34217/PDF**
Nuclear	**http://www.apnga.com/i_gauge_basics.html**
Near-Infrared	**http://en.wikipedia.org/wiki/Infrared_spectroscopy**

If you have other suggestions for references, please submit them to us and we'll add the relevant resources to this list.