Article for the 29th Sensing Forum

Control Method for Weighing Instruments Using the Environment Logger AD-1687

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Organized by: The Society of Instrument and Control Engineers (SICE)

September 27 to 28, 2012

Hitachi Campus, Ibaraki University

Ibaraki, JAPAN

Control Method for Weighing Instruments Using the Environment Logger AD-1687

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Abstract
We report on the error factors for weighing data which are caused by environmental factors and show how to improve repeatability which is important for measurements with balances. Data used was taken by the environment logger AD-1687 over a long duration. We also report analysis examples which improve repeatability.

Keywords
Analytical balance, Environmental error factor, AND-MEET

1) Introduction

Many electronic balances are used in laboratories and quality control fields. Presently, high-sensitivity analytical micro balances are available on the market which can display measurements as small as 1/100th of the weight of a 1 yen coin (1µg or mcg). The resolution capability of these electronic balances reaches 1 in 20 million parts of the maximum measureable load. Due to the high resolution and microscopic display capabilities, changes in the immediate environment of balances can lead to instability in measurements. *1 It is therefore regarded as essential to assess the installation environment of analytical balances with specialized tools in response to the many problems that can occur with such high resolution instruments. In order to resolve this potential problem we have recently developed the Weighing Environment Logger AD-1687*2

The AD-1687 detects not only temperature, humidity and atmospheric pressure, but also the level of vibrations balances are subject to. If the optional water temperature sensor is used, six different measurement parameters can be logged together in one reading (including the actual weight measurement). Further, timing of the measurements can be set freely by the user at intervals of as small as one second apart, with all six parameters being logged as a distinct measurement set. The AD-1687 can record up to 10,000 of these sets and display this measurement data in a time series graph. For example, by using this environment logger for continuous measurements of weight and environmental data over a 24 hour period, clear judgment can be made on many environmental factors that are beyond normal human perception, such as loss of stability and repeatability from people entering and leaving the measurement room, the influence of the smallest earthquakes, the slightest fluctuations in temperature from automatic air conditioning control that would go unnoticed by staff and changes in atmospheric pressure and humidity from outside weather. By confirming these environmental influences the precise cause of any measurement instability can be properly ascertained and measures to correct these influences can be performed.

The following cases present clearly identified environmental error factors that affect weighing results, based on data taken over a long time duration using the environment logger. Moreover, concrete measures to improve the repeatability of balances with actual measurement examples will also be reported.

2) Measuring environmental data

The specifications of the Weighing Environment Logger AD-1687 and the environment measurement method using a microbalance are as follows: The AD-1687 is compact-size, drip-proof (IP65) with a durable body for portable use and can withstand a fall of up to 1.5 meters. Also, since the humidity sensor is a disposable item, it is placed in a separate box with the temperature sensor, which is then connected with the logger via a connector. This makes it easy for the user to exchange the humidity sensor.

In tests of the AD-1687, BM-20 analytical balances with minimum measurement display of 1μg were used. The BM-20 has a weighing capacity of 22g, hence a resolution capability of 1 part in 22 million. These balances and environmental loggers were set up next to each other as in Fig. 1 and repeat measurements were conducted over a 24 hour period, automatically moving an embedded 20g weight up and down on the balances. An environmental logger was connected to each micro balance and while weight was being measured environmental data was also recorded for temperature, humidity, atmospheric pressure and vibrations. The AD-1687 unit can be seen in Fig. 2.

Fig.1 Alignment of balance and weighing environment logger

Fig.2 AD-1687

The results of measurements over the 24 hour period are displayed in Fig. 3 for reference. The cycle of up-down movement of the weight lasted 60 seconds and data was captured for both full load and zero balance every minute, resulting in 1440 data sets over the 24 hour period. The difference of span between full load and zero balance was measured and repeatability (standard deviation) was calculated for every 10 neighboring span values. Each repeatability value was then plotted as a dot and connected by a zigzagged line as shown in the graph below. The x-axis measures the time scale over the 24 hour period, the left y-axis measures repeatability in 1μg units and the right y-axis measures the change in room temperature where the weighing measurements took place.

This data was obtained from a test conducted at our company's main point of production, our factory in Tsukuba, Japan. Throughout the 24 hour period, an average repeatability of 1.3μg was maintained, easily meeting the catalog specification criteria of the BM-20 of 2.5μg for 1g of weight. Over this 24 hour period room temperature was found to vary by approximately 2°C, and although not represented on the graph, humidity varied by 4% and atmospheric pressure by 3 hPa. The data indicates that as the number of people who were allowed to enter the room was limited, under these environmental conditions even without an external tabletop breeze break or anti-vibration table the basic performance of the microbalance could be maintained for 24 hours. The evaluation method for relating measurement repeatability to environmental error factors has already been established as "AND-MEET" *3 and is conducted at various locations of use of a balance in response to users' requirements.

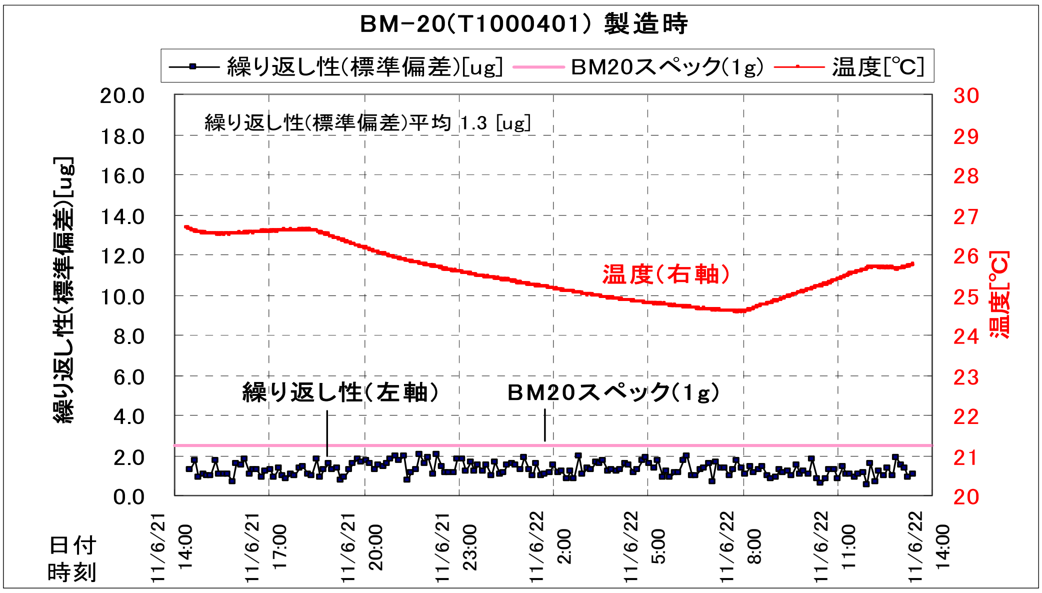

Fig.3 Example of weighing environment measurement

3) Measurement results

From the results displayed in Fig.3 it was confirmed that the microbalance performed with good repeatability under an ideally equipped environment, requiring neither an external tabletop breeze break nor an anti-vibration table. However, it was still necessary to confirm the effect such items may have in reducing external disturbances in measuring environments where these occur regularly.

Therefore, to try and replicate the type of environment in the field where external disturbances are frequent we selected the 2nd floor scale verification room in our R&D Center in Kitamoto, Saitama, Japan. In our scale verification room there are many people coming or going to inspect weighing scales, 20kg weights being loaded or unloaded, doors being open and closed and many disturbances of air by people moving around the room or from the air con unit. The arrangement of equipment for this test in our scale verification room can be seen in Fig. 4. In the photo you can see two high-capacity industrial balances performing measurements for verification. In front of them alongside the wall you can see two analytical balances taking data for this experiment.

Fig.4 Scale verification room

① Influence of air conditioning or people's movement and effect of anti-vibration table and tabletop breeze break (Fig.5 & 6)

The results of the test for repeatability conducted on August 10 (Friday) this year from 3 pm until 3 pm the following day are displayed in the graphs in Fig. 5. Fig. 5-1 shows results where the anti-vibration table and tabletop breeze break were used, Fig. 5-2 shows the results where they were not. Until Friday evening, when many people were still working in the verification room the repeatability results for both tests were bad and large differences can be seen in the values. Further, after the busy Friday evening period the graph on the left shows that repeatability fell below 2.5μg, within the catalog specifications for the standard deviation for repeatability (σ^{n-1}). However, the graph on the right shows a worsening of repeatability, exceeding the specifications on several occasions.

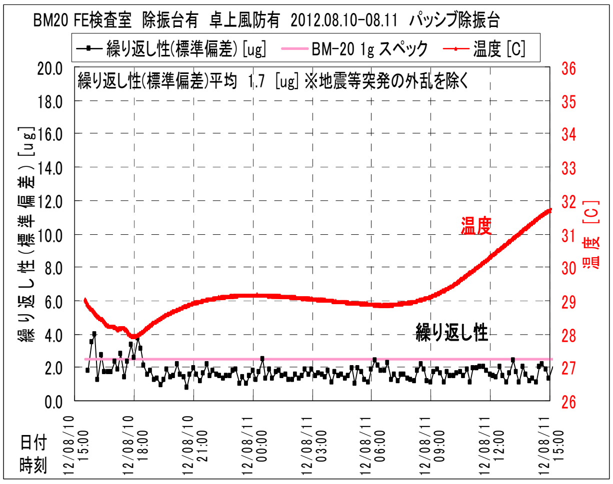

Fig.5-1 With anti-vibration table and tabletop breeze break

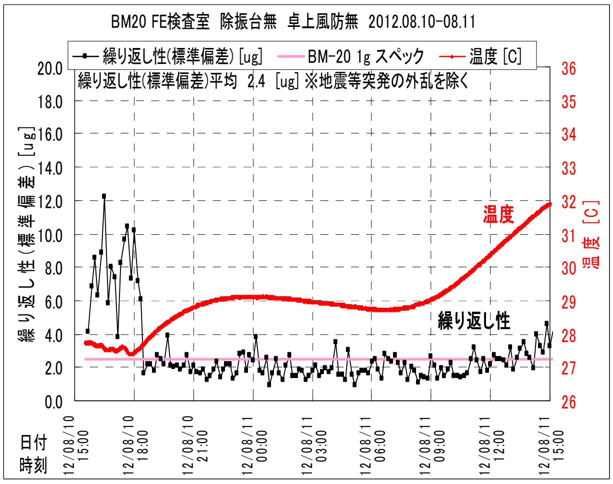

Fig.5-2 Without anti-vibration table and tabletop breeze break

In this test, room temperature, humidity and vibration data were simultaneously recorded by the environmental logger and are displayed in the graph in Fig. 6. This graph shows that over a 24 hour period room temperature changed just less than 4°C, humidity varied by a maximum 10% and vibration force was within 2-5 Gal. It also shows that until Friday evening when the worsening of repeatability was observed, there were humidity changes of 10%/30 minutes accompanied by minute fluctuations in room temperature, which was probably caused by the air conditioning.

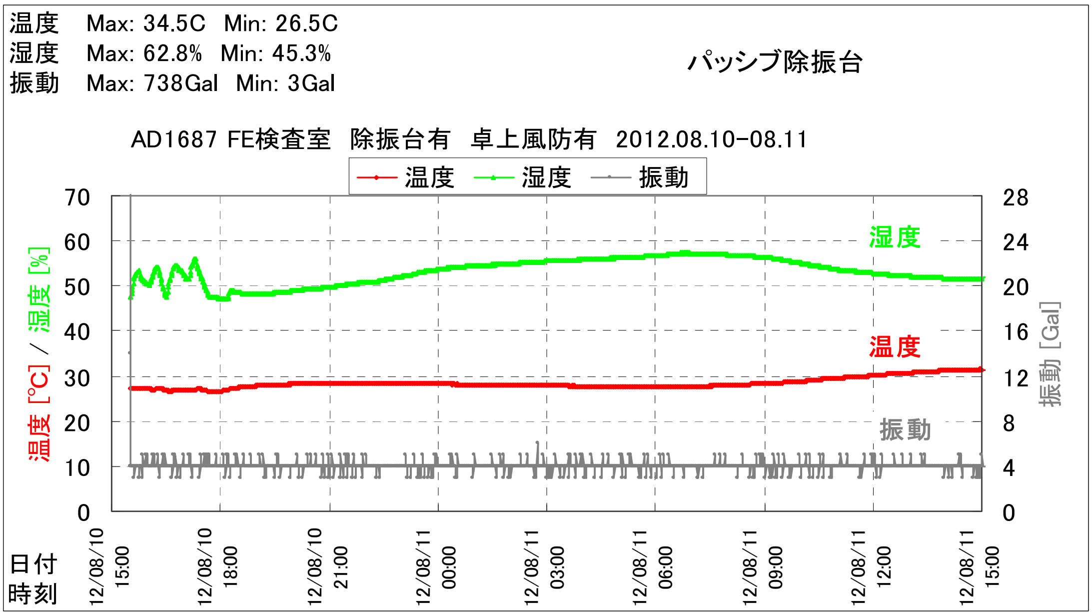

Fig. 6 Environmental logger data (temperature, humidity, vibrations)

From Fig. 5 & 6 we can determine that adverse effects from vibrations generated by the movement of people or from air movement from air conditioning can be mitigated by the use of tabletop breeze break and anti-vibration table, which can improve repeatability at the microgram level. Even after the effects of people's movement or air conditioning had ended after Friday evening, and also when experiencing non-controlled natural temperature changes, environmental error factors can be reduced by the use of tabletop breeze break or anti-vibration table. In this test, they led to a reduction of repeatability from a 2.4μg average to 1.7μg, a small but clear improvement.

② Influence of earthquakes (Fig. 7 & 8)

The metric structure of electromagnetic equilibrium balances is the same as that of high precision seismographs. Therefore, the reaction of these to earthquakes is extremely sensitive. Judging from their resolution capabilities, analytical balances should actually have a higher level of sensitivity than seismographs.

Data from the time of an actual earthquake is displayed in Fig. 7. The graph is a record of repeatability of weight measurements and room temperature from 3pm on July 2 (Monday) until 3 pm the following day. On July 3 (Tuesday) at 11:31am there was an earthquake in Tokyo Bay of Magnitude 5.4, or Level 4 on the Japanese seismic intensity scale. Shaking was also confirmed at the testing location. At that point in time, the repeatability of the balances slipped significantly, from a prior average of 2μg to a sudden increase to 20μg. Fig. 7-1 shows measurements performed with an anti-vibration table; Fig. 7-2 performed without one. Further data from the environmental logger is displayed in Fig. 8, where 14 Gal vibrations were detected from the earthquake (equivalent to about Level 3 in seismic intensity).

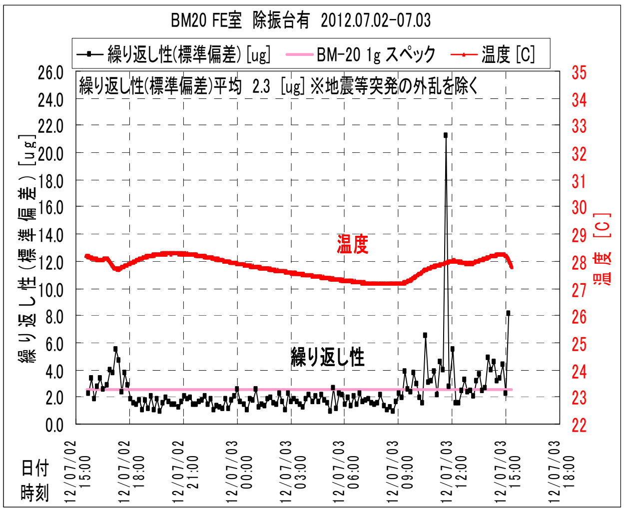

Fig. 7 - 1 With anti-vibration table

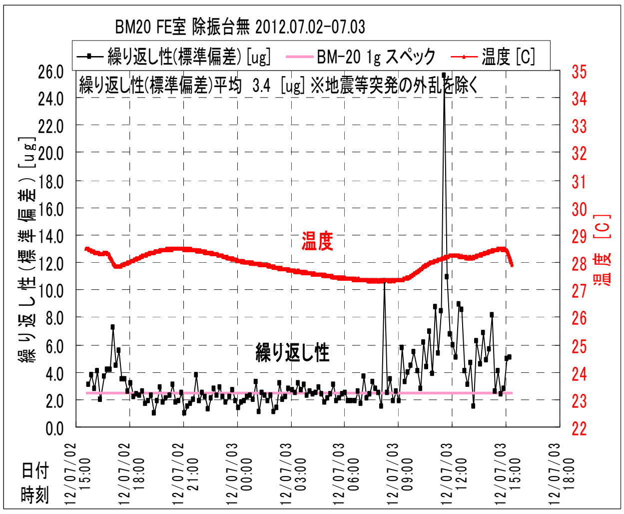

Fig. 7 -2 Without anit-vibration table

From Fig. 7 it can be seen that while an anti-vibration table can stabilize measurement values under normal conditions, with respect to large low-frequency shaking such as an earthquake it is quite ineffective and the balances have no ability to record reliable data.

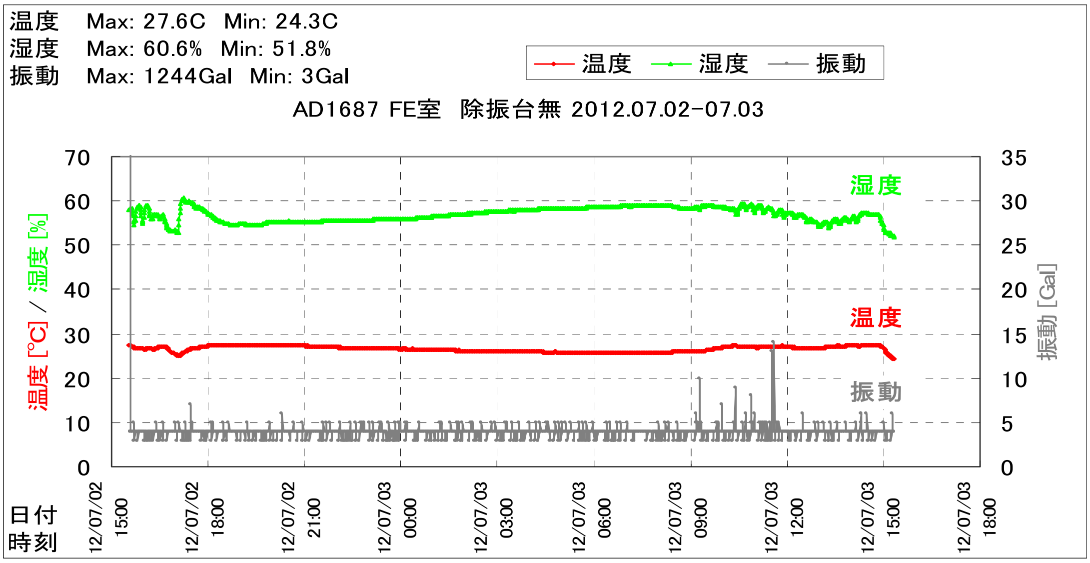

Fig.8 Environment logger data (temperature, humidity, vibration)

③ Influence of weather (Fig.9, 10 & 11)

The graph in Fig. 9 shows the influence on indoor environmental conditions from changes in the weather. The data shows changes in temperature, humidity and atmospheric pressure over the course of four days, from July 6-9 (Friday – Monday). From the night on the 6th until the night of the 7th, the test encountered low atmospheric pressure of 990 hPa. Around this time there were changes in atmospheric pressure of around 10-15 hPa, accompanied by 15% changes in humidity.

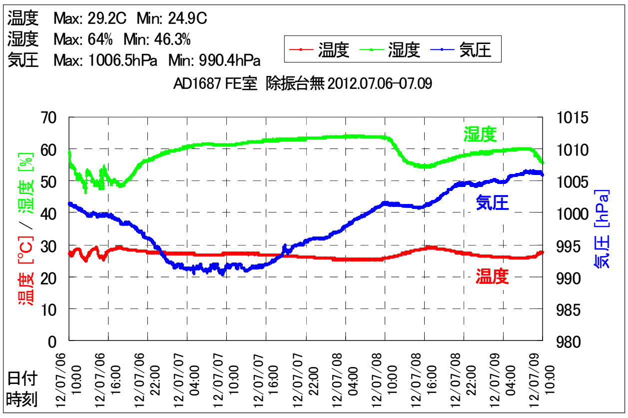

Fig.9 Environment logger data (temperature, humidity, atmospheric pressure

The change in weighing data from this period is shown in the graph in Fig. 10. There were only changes in temperature of around 2.7°C, but this led to a slow drift in the zero balance of as much as 1500μg. Further, it was noticed that the variation of span between the measured load (20g) and the zero balance was as relatively small as 200μg. The repeatability results from this test are shown in the graph in Fig. 11. During

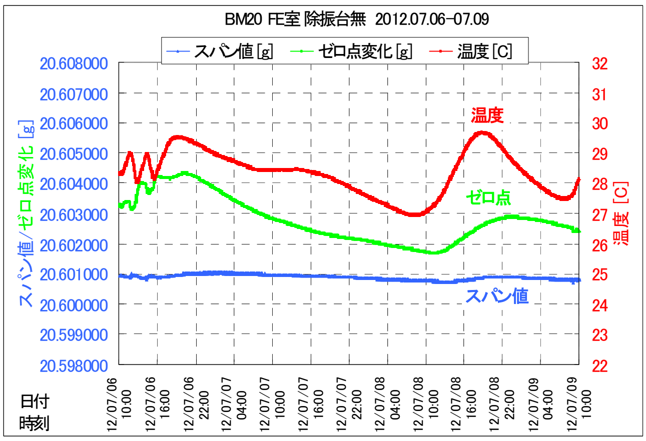

Fig.10 Weighing data (temperature, zero, span)

working hours on Friday repeatability ranged between 2-8μg, however, after this period it stabilized and fell under 2μg. There was also one other disturbance in repeatability and this occurred late at night on Sunday. This was caused by a Magnitude 6.1 earthquake that hit the Chishima archipelago (Kuril Islands) at this time.

From the above results, we can see that gradual changes in atmospheric pressure and humidity due to the passing of low-pressure systems, etc. did not influence the stability of the span value. Rather, short-term changes in temperature due to air conditioning, etc. had larger effects as repeatability was worse until 4pm on the Friday.

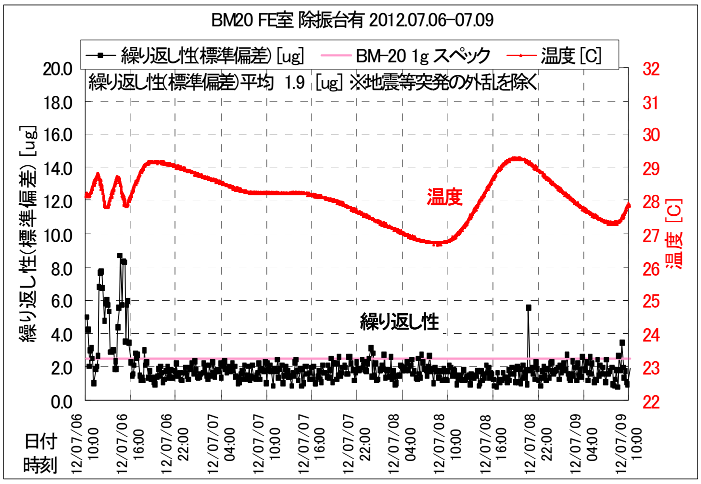

__Fig.11 Repeatability under a passing low-pressure system__

Repeated 24-hour data collections provided a good deal of information on the influence of earthquakes, movement of people, air conditioning and changes in temperature, humidity or atmospheric pressure on the repeatability of analytical balances. From the results it is clear that the largest causes of instability in measurement data are firstly the movement of people in the test environment, as well as effects from air conditioning; and secondly the influence of earthquakes.

Regarding changes in humidity or atmospheric pressure, slow drift of the zero balance caused by these factors was confirmed, but as this drift problem can be solved simply by resetting the zero balance, any influence on repeatability can be eliminated by devising appropriate operating procedures.

4) Environmental influence

We can say from the findings of our series of tests that the biggest disturbances on measurement data from analytical balances are the movement and comings and goings of people in room where the balances are set up as well as air movement from air conditioning units. Further, while meteorological phenomena or earthquakes cannot be ignored, earthquakes will end after a brief period and the only significant effect of gradual changes in meteorological conditions on balance measurements is a drift in the zero balance. As the zero balance can be reset each time before measurement, the influence of these environmental factors on the repeatability of the span value can be reduced simply.

Air conditioning is essential to ensure a constant room temperature. However, it is also clear that the slight periodic changes in temperature (temperature ripples) caused by air conditioning also have a significant effect on the performance of analytical balances. The influence of each of these types of disturbances cannot be completely eliminated, but it is clear that anti-vibration table or tabletop breeze break work effectively at improving repeatability at the microgram level.

5) Summary

Analytical balances, which are of especially high precision among weighing instruments, are vulnerable to slight environmental changes that cannot even be felt by the user and that invite display instability This leads to confusion over the quality of the balance itself and makes interpreting data difficult. In this type of situation, even if the measurement device maker conducts inspection tests to study the cause of any instability, the situation can be quite hard to reproduce and there will be difficulties correctly determining the cause. Also, naturally, users will want to conduct measurements with the degree of precision required for their own purposes.

In order to understand and solve this kind of problem there must be thorough investigation and evaluation of the measurement environment in order to improve this environment. Moreover, measurement device makers have a duty to provide information about environmental factors to reassure users and help them effectively conduct their measurements, and offer suggestions on correct setup of the measurement location. In order to realize this it is necessary to properly measure the environmental factors in the measurement room, and the AD-1687 environment logger, as well as the AND-MEET, or 24-hour weighing data monitoring system, are ideal tools to evaluate these. If these tools are used correctly they can certainly create effective conditions for precise measurement.

References

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