

Notes on Maintaining Sub-1V Balance of an Ionizer

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Abstract - This paper discusses steps necessary to undertake and technical details on setting up and maintaining sub-1V balance in the ionized environment. Specifics of closed-loop control are discussed. Results of tests under various conditions are presented.

I. Introduction

Requirements of the ionization balance in critical environments have tightened in recent years, mostly guided by increased sensitivity of magnetic heads. In many factories maximum imbalance is set to no more than +/-1V or even tighter. The impact of ionizer balance on safety of magnetic heads and other components is outside the scope of this paper. Discussion is concentrated on how to achieve and maintain sub-1V balance requirements.

Balance variations come from several sources:

- Initial imbalance
- Short-term drift
- Long-term drift
- Air flow variations
- Humidity and temperature of air
- Others

2. Comments on Instrumentation

Initial imbalance is usually either error of an operator or that of measurement equipment. Special attention needs to be paid to the performance of an instrument that is used to measure the balance. A typical charge plate monitor (CPM) has a scale of +/-1000V and specified accuracy of +/-1% of the full scale, meaning that the best guaranteed accuracy is +/-10V, which is 1% of 1000V. Obviously, such instrument, regardless of its traditional appeal and apparent ability to display low-voltage numbers, is entirely unsuitable for sub-1V measurements. Ideally, the instrument with accuracy of at least 10% of the required measurement scale of +/-1V, i.e. being able to accurately resolve +/-0.1V is

desired. Resolution should not be mistaken for accuracy. An instrument that is capable of displaying many decimal numbers does not necessarily possess the ability to display accurate numbers.

Another important property of equipment for adequate measurement of balance is its reaction speed. Overly slow measurement devices such as regular CPMs or especially, traditional CPMs with a small plate, will apply “low-pass filtering” of the data, hiding short-term drift variations and displaying artificially low numbers. If such “averaging” needs to be done for statistical purposes, it is recommended to do such averaging in post-processing, i.e. using data acquisition or facility monitoring software capability, but have real-time data available for proper adjustment and analysis.

It is strongly recommended that for measurements of balance to verify specifications, fast instruments should be used.

3. Drift

The absolute majority of ionizers have internal means of controlling the balance via its sensor grid or similar means. This allows keeping ionizer balance within a certain window. Some of the ionizers specify a maximum of +/-3V long-term self-controlled balance window under controlled circumstances. There are a number of factors preventing further tightening of this window, including environmental conditions that a local sensor of the ionizer cannot take into effect. Deviations of balance with time are defined as drift.

3.1 Short-Term Drift

In essence, short-term drift is random noise-type variations of balance lasting no more than few seconds. An example of such short-term drift is shown in Fig. 1.

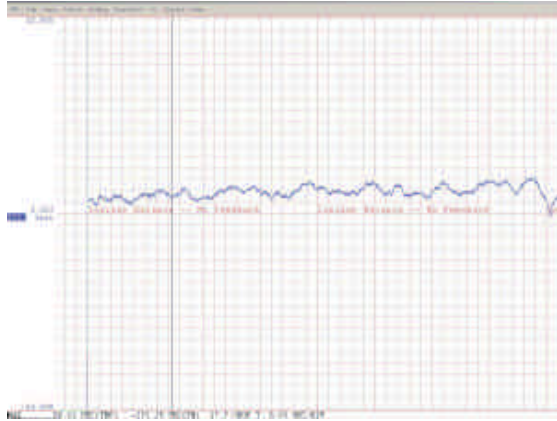


Figure 1. Typical Short-Time Drift of Uncontrolled Ionizer

For the purpose of meeting specification, it is important to control short-term drift to within $\pm 1V$ or less. Short-term drift is typically caused by a combination of instability of internal power supply and control circuit of an ionizer and of random variations in air humidity and temperature. Short-term drift is always present in an ionizer, even if its circuit were perfectly designed. Short-term drift is often missed if a slow measuring instrument is used. This doesn't make it anywhere less important to keep short-term drift within specification.

3.2 Long-Term Drift

Long-term stability variations add to short-term variations. Long-term stability is affected by air humidity and temperature. Long-term variations usually exceed short-term variations by significant margin. If an ionizer left unattended for extended period, natural wear-off of the emitters further contributes to potentially significant balance drift.

4. Need for a Closed-Loop Control of the Ionizer

With a maximum ability of an ionizer to maintain $\pm 3V$ balance at best by itself, other measures are needed to keep the balance within specification. A remote

sensor providing control signals to the ionizer can maintain much narrower balance range at the place where it is needed the most – at the workbench surface. A typical configuration of an ionizer with remote sensor is shown in Figure 2. Such devices were in existence for number of years; however sub-1V balance limitations introduce new requirements. Specifics include:

- Sufficient accuracy to be able to resolve sub-1V data
- Fast reaction speed to compensate for short-term drift
- Fast initial reaction time to settle to within specified range quickly
- Wide adjustment range
- Suppression of static field introduced by charged objects nearby.

As seen, a simple feedback sensor with a “generic” ionizer may not be able to meet these criteria. An intelligent sensor, i.e. ionizer controller that takes into account all of the necessary parameters for a critical environment, would be able to satisfy all of the above requirements.

It should be mentioned that these requirements apply to the complete system including the ionizer and its controller since the performance requirements specify the operation parameters of the entire system. Below we consider each item.

4.1 Sufficient Accuracy

Requirements for the accuracy and resolution of the measurement part of the ionizer controller were previously discussed above. As a summary, the device should be able to satisfactorily resolve $\pm 0.1V$. The measurement range is not expected to be excessive since the anticipated balance range is very narrow. It should be noted that design of such a device is not trivial and cannot be accomplished by simply increasing the sensitivity of a regular CPM and similar devices.

4.2 Fast Reaction Time

This requirement is crucial in the ability of the entire system to perform. Short-term drift of an ionizer can easily exceed 1V limits thus failing the specification.

Lets examine what happens when the ionizer system is slow. Figure 2 shows the equivalent timing schematic of the entire system. Every element has its delay. The least flexible from design point is the delay in airflow. It will always take a finite time for air to travel from the ionizer emitters to the work surface where the ionizer controller is placed. Ionizer control circuit in combination to the reaction time of its high-voltage power supply has its own reaction time. The best way

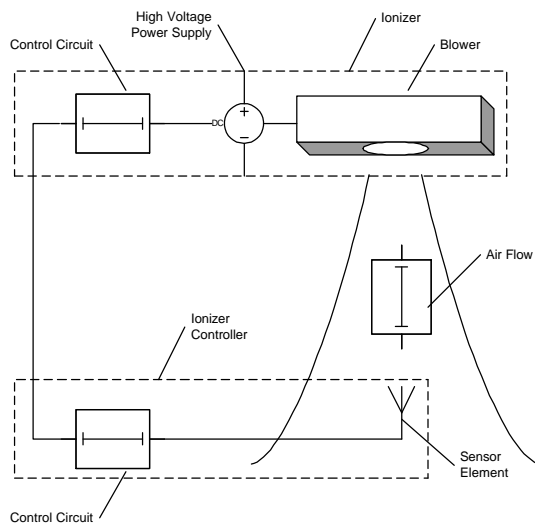


Figure 2. Closed-Loop Control Timing Diagram

to describe it is via a step function test where a sudden voltage change is applied to a control input of an ionizer and the resulting new balance of the ionizer is monitored. Figure 3 shows results of such a test. As shown, it takes 10.-12 seconds for this particular ionizer to be within 80% of the final value after applying a shift in control voltage. What is also clearly seen on this screenshot is short-term drift.

When the ionizer balance begins to drift for whatever reason, it takes time for the ionizer controller to recognize it, to react to it, and to issue a command to the ionizer to bring back the balance to within an acceptable level. Ionizer takes its time to process this information and then to apply changes in voltage to the emitters. Until that moment the ionizer balance continues to drift off target. After the correction is applied it takes time for the ionized air to reach the work surface. If the ionizer controller and the ionizer itself are slow, the variations of the balance resulting from short-term drift can be significant. On the other hand, if the reaction time of the overall system is sufficiently fast, the impact of the short-term drift is

negligible since such a drift would be largely compensated by the controller. Figure 4 shows the response of the same ionizer in the same setup connected to an ionizer controller where the only

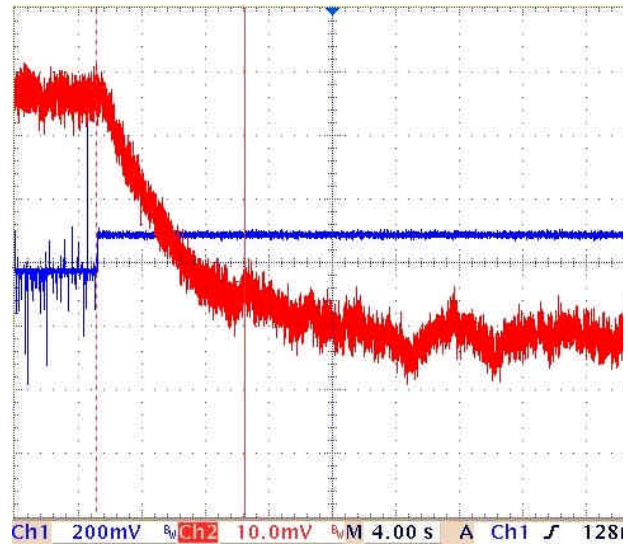


Figure 3. Step Function Test

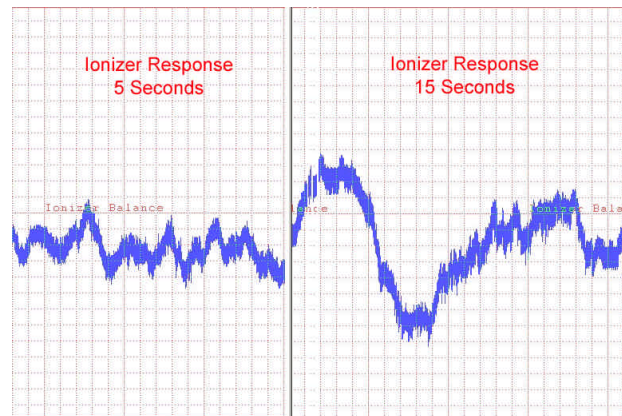


Figure 4. Short-Term Drift Compensation using Different Timing

change introduced is timing response of the ionizer control circuit. As seen, the ratio of balance spread is at least proportional to the response time of the ionizer. The same would be the case if the ionizer controller response time is too long.

Needless to say, the measurement equipment to observe the ionizer drift must be sufficiently fast in order to provide truthful information.

For the purposes of maintaining the sub-1V balance of an ionizer, it is required to reduce response time to minimum possible.

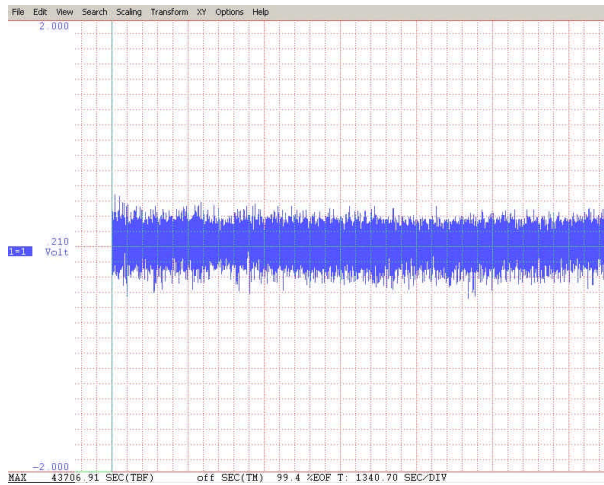


Figure 5. Long-Term Test of an Ionizer with Very Fast Reaction Time with Ionizer Controller. Balance is Kept within +/-0.2V

4.3 Large Control Range

Long-term drift may move the ionizer's balance significantly off. Worn-out emitters and other factors aggravate the situation. If the control range of the control system is narrow, i.e. within only a few volts, ionizer may not be able to support sub-1V specification and will need frequent maintenance. On the other hand, if the ionizer controller has a sufficiently wide range within it which can bring the ionizer to within +/-1V, this would not only keep the ionizer within specification for a long time, but it will dramatically increase periods between required maintenance and will lower requirements for the ionizer itself -- it no longer would need to be able to maintain its own balance within +/-3V. All this lowers

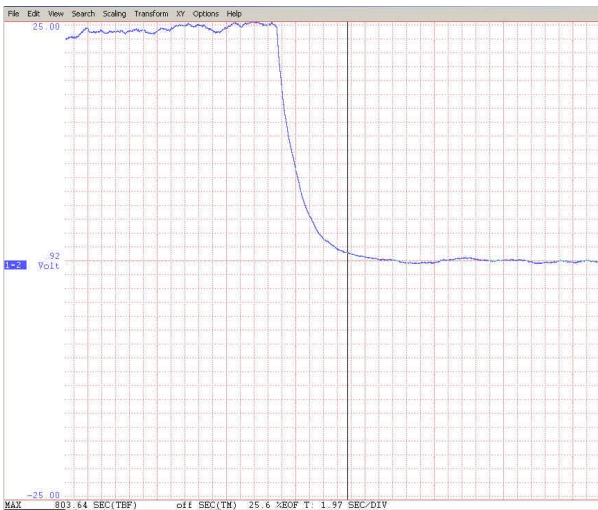


Figure 6. Ionizer Controller Bringing Balance to Zero from Over 20V Imbalance

the cost of ownership while maintaining sub-1V performance. Figure 6 shows the ionizer controller quickly bringing the ionizer to within compliance from 25V imbalance.

4.4 Static Voltage Rejection

It makes little sense to worry about +/-1V balance on the workbench only to allow the ionizer to be swayed by tens if not hundreds of volts by the sensor when a charged object is brought close to it. Such charged object may fool a simple sensor into believing that the balance of the ionizer has shifted resulting in attempt to correct for it. This action, of course, would charge all objects on the workbench to a high voltage by the ionizer. In such a case, no ionization at all may be more beneficial.

In order to avoid such damaging situation, an intelligent ionizer controller must be able to recognize

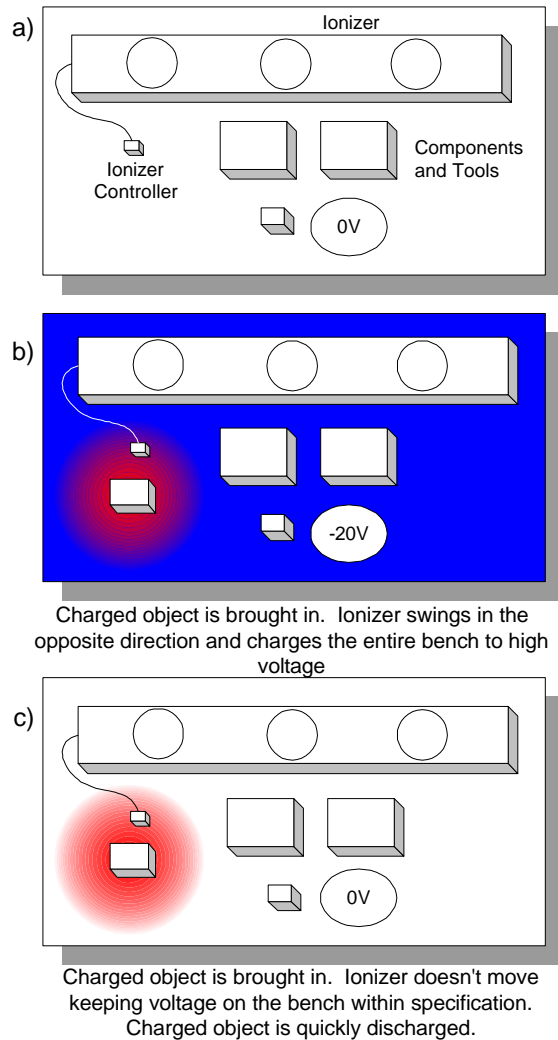


Figure 7. Influence of Static Voltage on Balance in Controlled Environment

what caused the change -- static field or genuine ionizer balance shift and suppress reaction to the static field. Figure 7 demonstrates what happens on the workbench when a charged object is brought in.

Figure 7a shows the desired 0V balance on the bench. Figure 7b shows what happens when a charged object, such as tray, etc. is placed close to the simple feedback sensor that swings the ionizer in the opposite polarity and charges all the components on the bench to an unacceptable voltage, rendering the entire purpose of

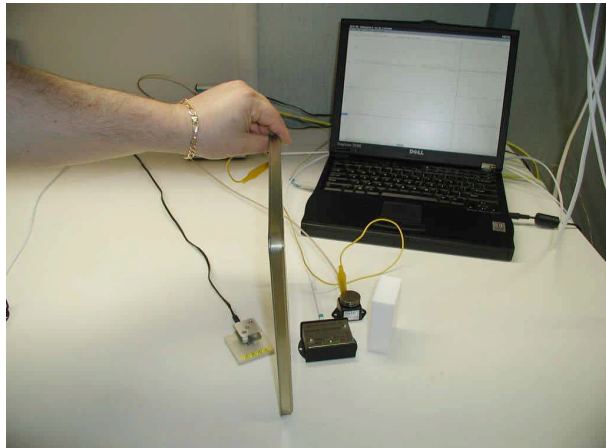


Figure 8a. Example of a Setup to Test Influence of Static Voltage on Ionizer Controller

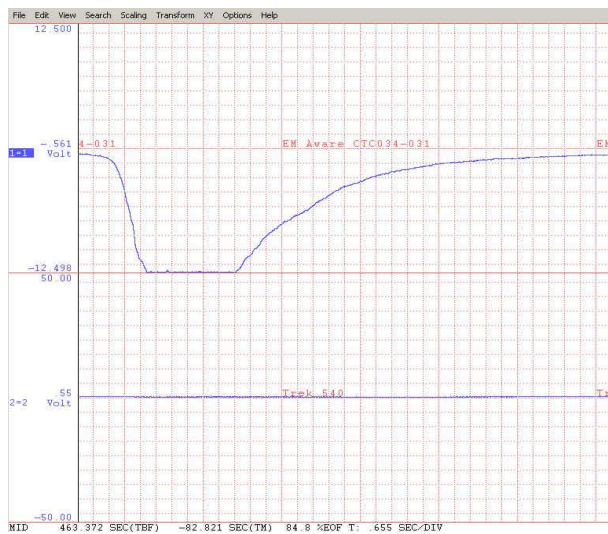


Figure 8b. Influence of Static Voltage on Balance in Controlled Environment

the closed feedback loop useless and action of the sensor harmful. Figure 7c shows that an intelligent ionizer controller does not change the balance of the ionizer regardless of influence of charged object which is discharged within seconds by the ionizer itself.

Figure 8 shows the proper setup for the test of influence of the static voltage on ionizer control loop.

Use of grounded sufficiently large metal shield is essential for test integrity. As seen in the top figure, an ionizer controller connected to the overhead ionizer along with the first sensor is placed on one side of the shield (held by hand) and the second sensor is placed on the opposite side of the metal shield. A charged teflon block is brought next to the first sensor and ionizer controller. The chart in Figure 8b shows the reaction of the first sensor to static voltage but no shift in ionizer balance as recorded by the second sensor.

It should be noted that simply slowing down the reaction of the ionizer and the sensor with the hope of reducing static voltage influence significantly worsens the overall performance (see previous section) with very marginal benefits to the rejection of static voltage.

5. Uniformity

To meet sub-1V requirements, the balance across the entire worksurface of interest must be within the set limits. For the overhead blower with two or three fans it is impossible to guarantee the sub-1V balance across the entire workbench if all three fans are controlled by the same ionizer controller. The reason for that is separate circuits for each blower that may drift at different rate in different directions. Ionizer manufacturers solve the problem by providing individual feedback control for each fan. At least one manufacturer employs one large squirrel-cage fan utilizing one circuit.

When testing for uniformity, it is imperative to allow sufficient time for the measurement sensors to settle since movement of the sensors and operator during repositioning can create measurement artifacts.

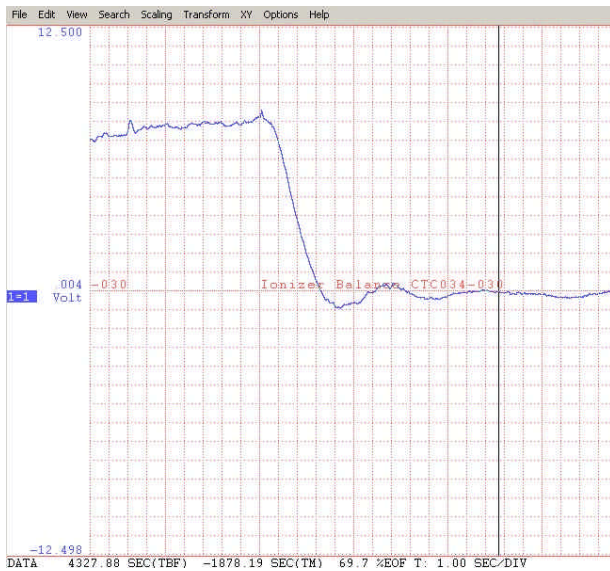
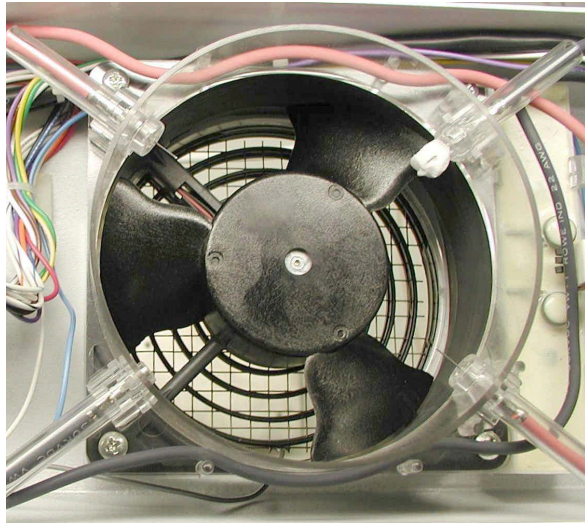
6. Decay

It should be noted that zero balance often indicates a dead ionizer. An engineer responsible for maintaining sub-1V environment should not be fooled by display of zero or near-zero balance only. In critical environments it is not enough to know whether ionizer balance is within specification but also whether decay of an ionizer at the proper location is within specified limits. Periodic checks with CPM may not be sufficient. An addition of continuous decay monitor, perhaps integrated into ionizer controller would provide better assurance of sub-1V environment.

7. Maintenance

For sub-1V environment maintenance of ionizer becomes an important factor. There are two main

factors that need to be watched. One is long-term self-drift of an ionizer. Left unattended, an ionizer without sufficient feedback control may drift off several volts within a month or two. Another factor is the wear of emitters which is unavoidable. Without well-designed feedback mechanism with a wide control range, maintenance may become a major burden.



For the purposes of testing the absolute worst case situation, a well-functioning ionizer was modified --

one of the negative emitters was removed and the second negative emitter was covered by a styrofoam “peanut” as shown in Figure 9. This is not a situation that is likely to occur in normal environment. An ionizer was offset and then the controller was enabled. As seen in the chart, it still was capable of bringing the balance within specified range, however a careful observer would notice “bumpiness” in comparison with the “good” tips in Figure 6. This example serves to show that with well-implemented ionizer control, the maintenance of a sub-1V environment may not be such a significant chore as it may appear to be.

8. Conclusion

Establishing and maintaining a sub-1V balance environment at the workbench cannot be done by simply applying new requirements for the existing equipment and procedures. The following steps are recommended:

1. Sub-1V balance requires higher levels of commitment (i.e. manpower and budget). Be ready for that.
- 2 Use ionizers with properly implemented fast closed-loop control with the ability to suppress static voltage influence.
3. Use instruments with sufficient resolution and accuracy to measure ionizer balance.
4. Use sufficiently fast instruments to measure ionizer balance.
5. Don't forget the most fundamental property of an ionizer -- decay.

References

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