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Rev. 2

Use of Correction Factors When Commissioning Air Systems

Contents

Introduction

This document is intended to be used as a reference document regarding the employment of correction factors when balancing air systems. The reason this document may be of use to the commissioning community is that, while all commissioning operatives have a basic understanding of factors and use them on a daily basis, many common misconceptions and misunderstandings exist. The intention is to supplement the largely theoretical information available from the compendium with some further, and perhaps more pragmatic detail.

What is a factor, and why use one?

A Correction Factor is a notional, established, and demonstrable value that is employed to align (by means of calculation) a measured, or indicated, air or water volume/flow to its "true" value.

In essence a correction factor serves only one purpose; it is there to compensate for circumstantial effects that compromise a given measurement, in some manner. A factorised measurement shall always therefore be a "true" reflection of the measured quantum of Air / Water volumetric flow-rate. Typically factors are associated with Air Volume measurements, so the majority of this document will be dedicated to discussion of Air Distribution Systems.

Why is using (more commonly described as "applying") a factor so important? In many, if not most, cases; put simply - it isn't.

Where all terminals on a branch/system are to share a common factor (most do, in practice), and assuming there are no leaks on the system, the factor will be of no material consequence and will simply be applied to the documented measurements retrospectively. It will have no effect on how the system is proportionally balanced or on its overall performance.

However, there will clearly be instances where there *are* leaks or deficiencies of installation; and in these cases the correct application of a factor is the main means by which they'll be identified during the commissioning process. This is the first good reason that a correction factor should always be applied (in the case of air systems).

The second key reason for employment of correction factors when balancing air systems; is that it is not uncommon to have different terminal types, or measurement methodology used on the same branch/system. In these cases, the various correction factors must be established in advance of proportional balancing. They must be applied in 'real-time' during the process, and re-verified on completion. Ensuring accuracy through this process is key to ensuring successful outcome, and is often advisable to repeat the factorisation process more than once prior to carrying out balance to be confident that the established factors are suitably robust.

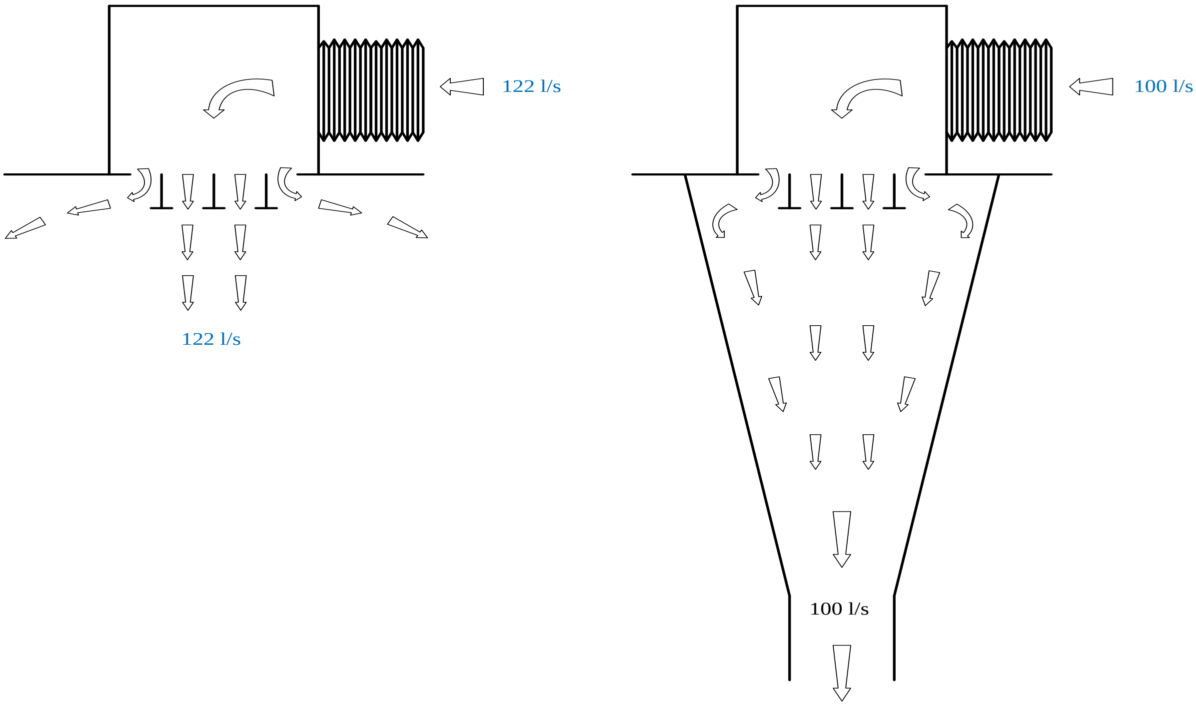
It would be ideal if it were possible to measure all Terminal Air Volumes by in-duct Pitot Traverse and not need any form of Correction Factor. However, it is highly improbable in any installation that all terminals would have suitable duct-traverse positions available. Even if it were so, using this method would be so time-consuming as to be prohibitive. Well-used Correction Factors will prove every bit as reliable and demonstrable as if every terminal had been traversed (at least in every pragmatic sense).

What Does a Correction Factor Correct

Where a measurement discrepancy *can* be 'Factored-out' is under circumstances where it is common, consistent and has a predictable effect.

A good, and commonly encountered, example of this is where an Air Collection Hood is used to record Terminal Grille Air Volumes.

Fig. 1 – Linear Grille without & with Air Collection Hood in place



Indicated in *Fig. 1*, a Typical Linear Grille viewed in profile has an unrestricted Discharge Air Path to the space being supplied. This is important, largely, because the available Static Pressure within the grille Plenum is generally relatively small (typically circa. 20 Pa); as the air has only the resistance of the grille face left to overcome. The Air Velocity exiting the grille face will typically be circa. 1.0 m/s. As indicated on the right, with an Air-Collection Hood in place, the air-flow going directly downwards is largely unaffected, however, the air-flow travelling perpendicular cannot follow it's normal trajectory. This air is forced against the Hood at discharge velocity (1.0 m/s) and then redirected downwards exerting a pressure against the hood and back against the air-flow-itself. This is further compounded by the restricted opening of the hood, through which all the air must pass in order to be measured. All of the above creates a resistance to air-flow in addition to that which naturally occurs (i.e. Increasing required static pressure in plenum (from 20 Pa) in order to achieve any given volume. Un-factorised, this would result in the corresponding VCD being set such that static pressure within the plenum would be artificially high (e.g. 30 Pa). Once the hood is removed (the measurement having been recorded) this additional resistance is also removed, leaving the plenum pressure 50% higher than actually required and therefore (following square-law) delivering 22% over-volume.

Precisely because of the Square-law, however, this effect is common to all of the grilles to be measured. It is consistent between them, and is therefore entirely predictable.

In this example, assuming 20 Pa = 100 l/s and use of Hood adds 10 Pa (at 100 l/s volume).

Then 45 Pa will deliver 150 l/s, and use of the Hood will add 22.5 Pa (at 150 l/s volume).

Therefore (20 Pa + 10 Pa) = 30 Pa = 122 l/s (+22% of the measured volume)

And (45 Pa + 22.5 Pa) = 67.5 Pa = 184 l/s (+22% of the measured volume)

As demonstrated above, the measured volume is consistently 22% less than the 'true' volume delivered after the Hood has been removed from the Grille. Therefore a Correction Factor can be applied to these readings (1.22 in this instance) that can be relied upon to always return the measured volume back to its true value, *regardless* of the achieved volume.

The use of an Air Collection Hood is by no means the only instance where a Correction Factor is required, but the above described principle is always applicable: Provided the causal effects of the Correction Factor remain consistent – it will be reliable, and therefore demonstrable. Some other common examples are noted below:

Use of Balometers

Generally modern commissioning methodology will use a Balometer, rather than the more traditional means of air-capture hood and anemometer. A Balometer, is in itself an air collection hood, with a couple of notable differences. The Balometer combines the canvas hood with an in-built flow-grid; coupled to an integral micro-manometer. The 'neck' of the hood utilised by the Balometer is notably larger than would be usable with a traditional hood, with the flow-grid providing effectively complete coverage. At least coverage in accordance with the Log Tchebycheff Rule, and therefore representative of the true volume. The instrument is pre-configured to convert the recorded velocity into an indicated volume, which is read-out on LED display.

What should always be remembered is that though the Balometer does, indeed, record true volume through the hoods neck, this volume is still representative of the air volume *while the hood is in place*. Therefore, all the fundamental principles at play, and described; above still apply and the Balometer will still always require factorisation. Though it is true to say that correction factors are generally closer to 1.00 (no factor) when using a Balometer over Air-Capture Hood and anemometer combination. Balometers are generally preferred in the industry presently, as they appear more professional/reliable to the observer.

Differing Grille Types

Probably the most common grille types to be encountered are the linear-slot type diffuser (described in detail above); the 4-way blow diffuser (can be plated to convert into 1, 2 or 3-way blow); the Air-Valve (aka Punka Louvre) or the swirl-diffuser. Generally speaking, the 1, 2, 3 or 4-way blow diffuser and the air-valve will be least susceptible to the effects that create a factor and therefore will return a factor closer to 1.0.

The linear grille will in all likelihood return a factor in the region of 1.1 to 1.2. Swirl-type grilles are notorious in respect of the effects of using hoods or balometers, and the factors that are established can be quite high. The reason for this is fairly straight-forward; in that the air pattern discharged from a swirl grille is not only angled close to perpendicular to the ceiling (exactly as with a linear grille), but also angle to the side from each opening. Therefore, in order for the hood (or balometer) to channel the air down to the orifice, it's path must be re-directed through 2-planes of direction simultaneously. This significantly increases the additional resistance offered by the hodd, and subsequently the correction factor.

It should always be noted that the above is, by no-means, 'set-in-stone' and every case is different. This is precisely why correction factor should be established on every system, every time, casting aside and prejudice as to what the factor "should" be.

<u>How to establish and use a factor</u>

The basic principle of establishing a correction factor is to nominate a typical example of a terminal, measurement methodology and instrumentation. Where there are multiple variables of these on the same system to be balanced, multiple factors will need to be established. Nomination of a terminal to be used will be influenced primarily by the suitability of the associated duct-work to provide a stable and reliable in-duct pitot traverse. A compromised traverse will return a compromised Factor, so care should be taken.

Having nominated a suitable factorisation Terminal, it is measured using the method and instrumentation and methodology to establish its ‘Indicated’ air volume.

With no adjustments of any kind made to the system, it is then immediately re-measured using in-duct pitot traverse, thus establishing ‘Actual’ air volume.

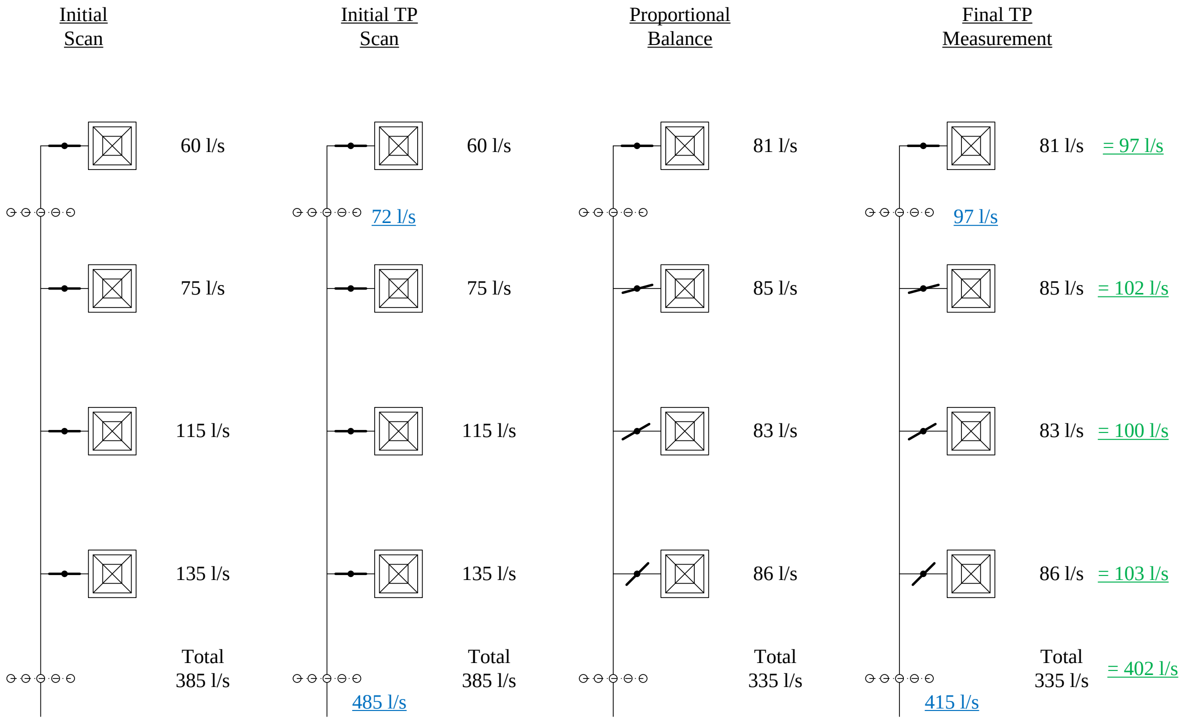
Put simply: - $$\frac{Actual\ Volume}{Indicated\ Volume} = Factor$$

<u>NB</u> – At the time the correction factor is established, the installation between the point of pitot traverse measurement and the terminal should be thoroughly inspected to ensure there is no leakage.

With the factor established, it is applied to all Indicated Air Volumes for all terminals on the branch to be balanced. The total of these factorised values should be consistent (-5% / +10%) with the initial main branch volume measurement by pitot traverse. If this is not the case, further investigation is required and balancing should not commence.

Following proportional balancing; the factorisation traverse measurement is repeated, as is the main volume pitot traverse at the same time as the final scan of the Indicated air-volumes. It is only at this point that the final correction factor can be established and documented.

Fig. 2 – Employment of Correction Factor



Demonstrated in *Fig. 2* are the stages involved in factorising a very simple branch of a typical air system. Having completed initial scan of the terminals a total Indicated volume of 385 l/s is recorded. The nominated Factorisation Terminal is traversed establishing True volume of 72 l/s, where indicated is 60 l/s; therefore:

$$\frac{72\ l/s}{60\ l/s} = 1.20$$

Applied to the total: 385 l/s x 1.20 = 462 l/sec. The branch main traverse position is recorded as 485 l/s; which is 5% higher and comfortably within tolerance.

The system is then balanced, changing the dynamic and all Indicated & Actual volumes.

Both Traverse positions are then re-measured, returning the same factor (as it should) and returning a factorised total volume of 402 l/s, with main TP now 415 l/s (+3%) and still comfortably within tolerance.

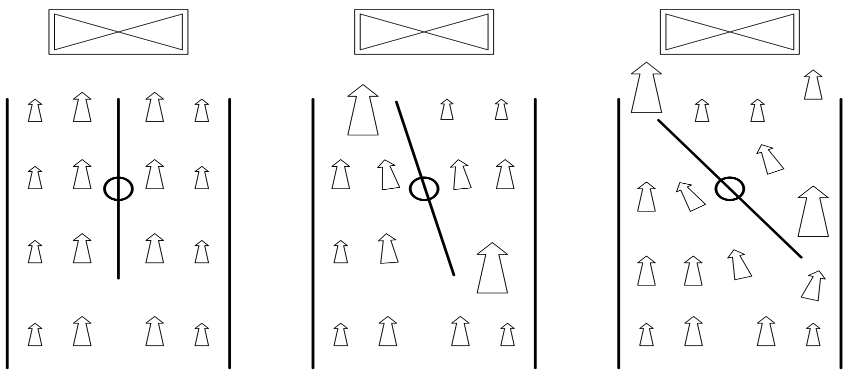
The purpose of re-recording the factor on completion, is that one cannot document (for record purposes) the 72 l/s & 60 l/s values the factor was originally calculated from; as they are no longer relevant to the system in its finished state. Therefore, they are not demonstrable (without de-regulating the system back to its unbalanced state).

What Doesn't a Correction Factor Correct.

There are a number of common 'causes' for a measured reading to not be true reflection of the actual achieved Air Volume. These should *never* be confused with measurement inaccuracies, tolerances or proportional bands. There will always be inaccuracies in any means of measurement; however these are as likely to give a reading that is artificially higher; as artificially lower. In reality there will be a mixture of higher & lower readings, and these could alternate between terminals and even on the same terminal if a number of measurements are repeated. For these reasons that cannot be factored-out, and this is not the intended purpose of a correction factor.

A good commonly encountered example of this is Single Bladed Volume Control Dampers installed on the end of Fresh Air Spigots.

Fig. 3 – Vane Anemometer readings taken on Spigot with VCD at various positions.



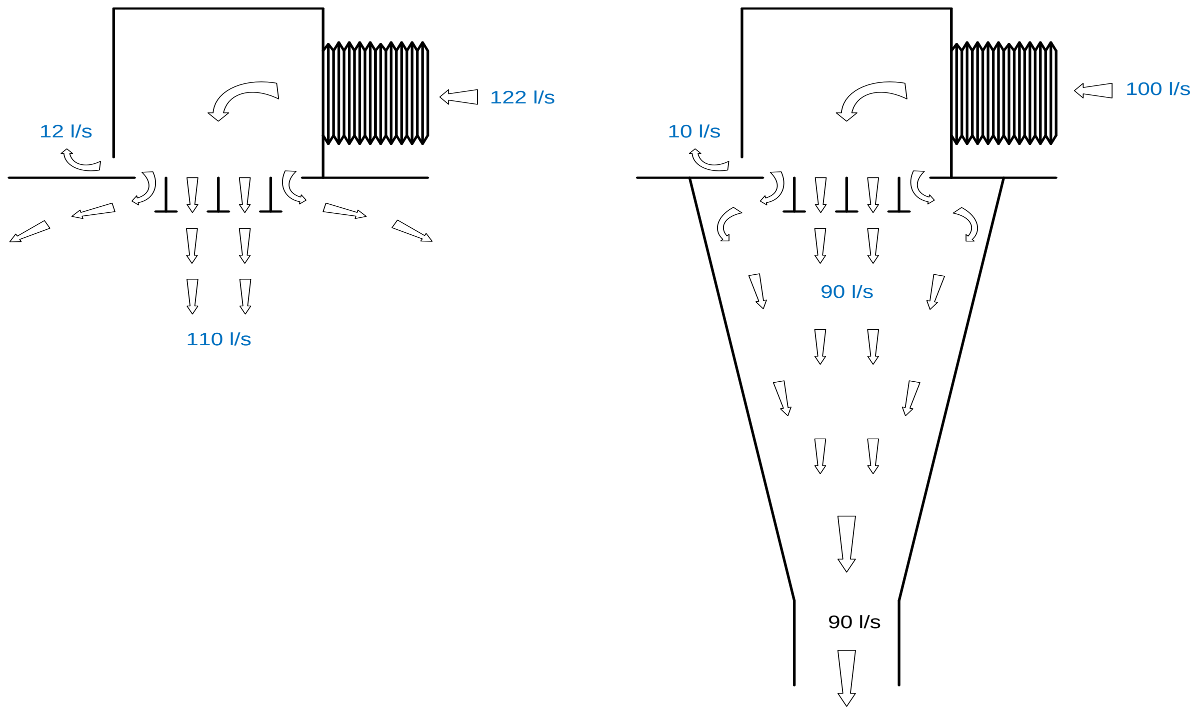
As can be seen in *Fig. 3* above, with the VCD fully open the Anemometer vane is tending to capture the air moving down the centre of the duct, where velocity will be highest (owing to frictional losses at around the periphery). As the VCD is regulated, the air pattern changes drastically with areas of higher/lower velocity, dependent on the VCD blade position; and on air volume passing over it. The VCD position, and the volume, are infinitely variable – as are the effects and therefore this is wholly impossible to predict. A correction factor can (and will) **not** mitigate this effect. In this instance it is advisable to establish correction factor on an unregulated terminal; where the reading is least compromised. Noting that it is probable, for the above described reason, that a negative (less than 1.0) factor will be returned. This should still give a total terminal (factorised) volume that is consistent with the measured total volume by pitot traverse.

NB – When encountering an Installation where spigots have Single Bladed VCD installed at the end, the Commissioning Engineer should identify this issue to all relevant parties. Use of IRIS type VCD or SBD adjacent main duct-work will mitigate this issue, but the reality is that this is considerably more time-consuming/expensive and this may be deemed to outweigh the negative effect of reading inaccuracies.

There are numerous other effects on a readings accuracy; ranging from the inherent accuracy of the Instrument in use (likely to be +/-3% at best) to simple human effects (e.g. the instrumentation will not always be held exactly in same position for every reading, etc. etc. The salient point is that none of these effects are mitigated by the use of a Correction Factor.

Arguably the most misconceived "cause" of a Correction Factor is duct-work/plenum/grille leakage. This must never be considered to influencing the returned factor, in fact it would be true to say that this is almost the polar opposite of a correction factors true purpose. That is to say, a properly employed Correction Factor will **reveal** and not **conceal** leakage.

Fig. 4 – Linear Grille leakage from poorly sealed Plenum



Illustrated in *Fig. 4*, an air-collection hood is placed over a poorly sealed terminal. The recorded 90 l/s is calculated against the known air volume of 122 l/s, as measured by pitot traverse serving the grille; which calculates to a factor of 1.36. However, the true factor is 1.22, (the air volume actually discharged from the grille is 110 l/s / 90 l/s = 1.22). This value cannot be known when calculating the factor, meaning this factor can only be returned artificially high, using the information available.

The result of this will be that all subsequent terminals, where this factor is used, will be incorrectly set to a lower volume (even if properly sealed).

The correction factor should always be calculated from the volume discharged to the space, which must be the same as the pitot traverse volume at time of measurement. This can be accomplished either by ensuring nominated factorisation terminal has no leakage, or sealing any leaks on this terminal for the purposes of factorisation. Doing so ensures that subsequent terminals will be discharging the correct volume to the space, regardless of any leakage they may also suffer from.

Conclusion

In conclusion, Correction Factors are an essential tool in commissioning of air systems, when correctly used. Where systems require multiple measurement methodologies, it is impossible to correctly complete commissioning without applying factors. Where Terminal types and testing methodologies are uniform, the factor serves only to align recorded terminal air volumes with the known total.

It should always be remembered that the factor applied relates only to the instrument and testing method used at the time and therefore does not truly ‘exist’. The factor should always be repeated and re-calculated should system require subsequent re-visiting post commissioning stage.

Commonly factors will be 0.8 to 1.2, and investigation should be undertaken if a factor falls outside these parameters. However, this has historically been considered an absolute rule, but is no longer the case. Recent developments within the industry, and grille design, have resulted in lesser discharge air volumes; whilst maintaining the same air velocity to take advantage of the Coanda effect. This means, particularly in the case of linear/swirl diffusers that factors in excess of 1.2 are now common. Consideration to the setting of air-pattern blades should be given in these cases, as they will have a dramatic effect on the correction factor.

The preconception that factor must always all between 0.8 and 1.2 is all too common within the industry, and the Commissioning engineer may occasionally mount a robust defence of the factor. In these circumstances it should be remembered that the facts are the facts and provided correct procedures have been followed (and human error eliminated) the correction factor is what it is, regardless of any *opinion* to the contrary.