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Air Balancing Area Factors

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Balancing a zone's air-distribution outlets is a critical requirement for a complex system to be able to meet the design loads in all spaces. While relatively simple for constant volume systems, which often includes series fan-powered VAV systems, an air balancer forces a VAV system (or a section of a system) to go to full design airflow, typically by setting zone thermostats to call for full cooling in that zone. The balancer then must adjust balancing dampers in each diffuser (or better, the damper in the duct supplying the diffuser) to provide designed airflow at each outlet.

Measurement of the air supplied by an outlet can be accomplished by a traverse of the duct velocity (complex and time consuming), using a "capture hood" (a device that collects the airflow from a device and passes it through a measurement grid) or use a velometer to measure the discharge velocity at each outlet and convert that velocity to an airflow rate. The conversion from velocity to airflow rate requires a known "area factor," or A_k, which when multiplied by the velocity converts velocity to flow, or from fpm to cubic fpm. This value is not the measured open area of the outlet, but the "effective" free area, which is the ratio of the discharge velocity to the actual airflow rate. The challenge with the discharge velocity method is to come up with a discharge velocity measurement method that yields a consistent value, an issue compounded in complexity by the inlet conditions of the air outlet that seldom result in equal airflow across all sides of the device.

Air-distribution equipment manufacturers have long published "area factors" for balancing purposes, that is, until recent years. These values, however, are no longer being presented for a number of reasons. So, when a request is received, the first question asked is "What are you going to do with the value?" The second question is "What device are you intending to use?"

The A_k value is reported as a constant, reflecting the ratio of sensed discharge velocity to the measured air quantity. It is not based on any physical dimensional relationships. Rather, it is dependent on the type of device used to measure the discharge velocity along with the location and orientation of the device relative to airflows. For the A_k to be accurately applied, the sensor must be held in a proscribed manner and the data averaged in a specified array of measuring points.

The device used has to be clearly specified, as the geometry of the sensor greatly affects the value observed. In other words, two different devices may yield differing results when applied in an identical manner. Early area factors specified the use of an Alnor 2000 Series device with a 2220A tip on the sensor; later, it changed to the newer Alnor 6000 Series device with a 6070 tip. The 2000 Series used a single tube to transmit a pressure reading to a mechanical vane that was then connected to a gauge.

The 6000 Series units used two tubes and were typically more accurate and repeatable. The 6000 Series also had the ability to measure velocities in a duct using a different type of probe tip. Both were available with extensions that allowed the measurement of ceiling diffusers while standing under the outlet/inlet without a ladder. In the past, these devices were a single sourced "industry standard" for balancing systems, but times have changed. The 2000 Series device hasn't been sold for many years and the 6000 Series has seen limited sales in recent years. In fact, neither of these devices is commonly used at present, having been replaced

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by electronic devices that have a number of features, including the ability to record and average readings.

These newer measuring devices, typically hot wire or hot film anemometers, while much more accurate, convenient, and portable, are highly dependent on measurement location, sensor tip geometry, and temperature sensitivity. More importantly, there is no accepted "industry standard." The air leaving a diffuser or grille is typically a very thin and highly variable jet. The mechanical 2000 and 6000 Series vane anemometers, with the appropriate sensing tips, essentially averaged the air velocity in a repeatable manner, allowing for standardized presentation of area factors. The variety of hot wire geometries in the newer devices, usually protected by a shield to protect the sensitive film or wire, greatly affects the measurement when in close proximity to a surface. This means that while an area factor could be determined for one type of anemometer, it would not be valid for another.

As mentioned earlier, measurements of discharge velocities are, of course, greatly affected by inlet effects. The most common installation involves a 90-degree bend of the flexible duct that connects the diffuser to the HVAC system. This was discussed at length in an ASHRAE research project conducted at UNLV and was reported in the Journal in April 2012. Averaging the measured discharge velocity on all four sides of a square ceiling diffuser is a minimum requirement, but is probably not a perfect measurement technique.

A better and more common measurement technique is to use a flow hood to determine airflows into and out of air outlets/inlets. Unfortunately, these are not absolute measurement instruments. With a high induction device, which probably includes most ceilings and linear slot diffusers, there can be significant errors between reported and actual air quantities. Differences greater than 20% are not uncommon. They are difficult or impossible to use on duct-mounted grilles or installations with no ceilings.

The most accurate technique for determining airflow quantity is a pitot traverse in a straight run of duct. This is seldom practical, as straight runs of duct are not often found when needed, and typically have low velocities, making accurate measurements difficult. With VAV systems using pressure independent VAV boxes with multipoint averaging inlet sensors, proportional balancing can be a very effective technique. Most VAV box sensors are accurate to within 5% of the full-scale reading of the values presented on most manufacturers' products, given a relatively straight inlet to the terminal. (Note: It is highly unlikely that any VAV box sensor, from any manufacturer, is accurate to 5% *of reading* at minimum flow!) My advice, which I have presented at a number of NEBB sessions in the past couple of years, is to compare the VAV box sensor reading to the carefully aligned anemometer sensor readings from all the diffusers attached to that VAV terminal and then determine an "effective" A_k for that sensor and that type diffuser. (Note: One cannot assume that all the diffusers shown on the plans are actually connected to that VAV terminal, or even connected to anything, without actually checking). I also recommend adjusting the adjustable outlets as shown in the plans, such as slot diffusers. As mentioned in a prior article, adjusting a linear slot diffuser so that it no longer blows down on occupants will invalidate any prior system balance.

In any case, the reported or determined area factor cannot be used to determine the actual free area of an air outlet/inlet. The best way to compare actual free area between devices is to compare static pressure or sound levels, as they should be related. Blade configurations, angle, and the relationship to a specified probe location all affect the measured A_k and may have little relationship to the actual free area. This is especially true for return grilles.

So, when asked for these factors, manufacturers have to ask for what purpose the A_k value is to be used. In most cases, they find that the balancer is attempting to determine the air quantities and has a hot wire anemometer of some sort. When he is using one of the old Alnor devices, the manufacturer may have data for many products. Newer electronic devices, however, seem to be the rule. Most manufacturers recommend that the users determine their own area factors by carefully determining the airflow for a single device and sensor orientation and use this on others on the project. If the user wants to use the values for some diagnostic purpose, such as the actual discharge air velocity, that value is not reflected in the traditional A_k values. A better result can be found using software from the manufacturer and calculated throw data.

Until the time when a single anemometer and anemometer geometry again become the defacto industry standard, manufacturers will likely not be able to report area factors that can be used with any of the newer instrumentation types available. ■