
# The Cases *for and against* Manual Volume Dampers

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**Army Corps of Engineers' construction documents for a military hospital in Fort Bragg, N.C., show more than 2,000 manual volume dampers (MVDs) upstream of variable air volume boxes. However, the installation of these dampers became the subject of a dispute during construction. According to the subcontractor, the system was a "high-pressure" system, making MVDs detrimental to its operation.**

The government's opinion is that installation of dampers where shown and specified was a contractual requirement, even though the engineering necessity of installing the devices is debatable. After the government denied the contractor's claim to recover expenses involved in installing the MVDs, the contractor appealed to the Armed Services Board of Contract Appeals (ASBCA). A similar appeal also is pending involving a military hospital in Alaska. (For those interested in the final outcome, the Board's forthcoming decisions will be published under ASBCA Nos. 53431 and 51906.)

This article primarily covers the Savannah District (Fort Bragg) case, although some of the designer's reasons for including dampers on the Alaska District project also are mentioned. The basic issue in the Savannah District case is that MVDs were shown in 2,276 locations upstream of pressure-independent VAV boxes with inlet static pressures of more than 3 in. w.g. (747 Pa). The specifications called for MVDs, and specific details of ductwork upstream of the VAV boxes depicted MVDs. However, one note on one general detail for circular duct takeoffs reads, "In high-pressure systems do not install any splitter or volume dampers." (See *Figures 1a* and *1b*.)

The subcontractor argues that the systems in question are "high pressure," and that the draftsman made a mistake by copying a computer-aided drafting design (CADD) cell showing dampers throughout the plans. The subcontractor says the note negates thousands of indications that MVDs were required upstream of the VAV boxes, and that it "solved the dilemma" in his mind.

Before summarizing the cases for and against, let me caution that there are likely some "faulty arguments" advanced by the opposing sides. It is rare in a dispute that one side is completely correct and the other totally wrong. Therefore, one must use critical judgment and weigh the credibility of the supporting references that follow. The article concludes by suggesting procedures that might have made this a moot debate.

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## The Case For MVDs

The Army Corps of Engineers found the following technical reasons for insisting that MVDs be installed:

• The equal-friction method was selected by the architect-engineer (A-E) due to noise considerations. The static-regain method would have had smaller ducts and higher velocities close to the AHU fans, which would generate higher sound levels. The former method requires extensive dampering.

• It is important to provide properly balanced MVDs in run-out ducts upstream of each terminal to provide an appropriate stable inlet pressure at each terminal and minimize terminal generated noise (although the proximity of the MVD to the VAV box is a factor, since the MVD also generates noise).

• Unlike the static-regain method, the equal-friction method is not "self-balancing." To have the desired static pressure at the inlet to the VAV boxes, the use of MVDs upstream of the VAV boxes is required.

• The designer also chose the equal-friction method because of limited space. With the static-regain method, ducts at the end of the systems could become large, thereby making it difficult to fit everything in the allotted spaces.

• MVDs can be used for "fine tuning" the system.

• VAV boxes are rated within a certain range of airflows, inlet pressures, and differential pressure drops. If the airflows and inlet pressures entering the boxes exceed the manufacturer's published data, the result is higher noise levels.

• A manual damper is like insurance—it is better to have it and not need it, than to not have it and need it.

• In theory, balancing dampers are required in all paths at branches taken off from larger ducts, with the exception of the critical path (often called the longest run). Note: the true critical path has the highest-pressure requirement at the design airflow.

• Fewer MVDs could result in increased fan energy usage, as is explained later.

• Fewer MVDs can result in reduced flexibility to adjust to the changing air-distribution requirements of building retrofits or additions. While VAV boxes adapt automatically, it might be desired to manually direct more airflow down certain duct mains by adjusting branch MVDs.

## The Case Against MVDs

The appellant's technical objections are as follows:

• It is understood in the industry that MVDs are never installed in the "high-pressure" or "primary" duct system between AHUs and VAV boxes.

• MVDs are not needed upstream of pressure-independent (PI) VAV boxes. Their installation in such a fashion actually would be a detriment to the system. The VAV box controls are effectively a dynamic balancing damper, absorbing the excess pressure available in the system as pressure and zone airflow requirements change.

• The 1975 SMACNA standard for high-pressure ductwork (although it has been superceded and wasn't referenced in the specifications) states that static pressures 3 in. w.g. (747 Pa) or greater generally are considered "high pressure."

• The test and balance firm left all MVDs in the wide-open position, and the government accepted the project.

• The initial cost to install the MVDs and the resulting increased energy usage (due to unnecessary friction losses) are a waste of taxpayer money.

• Unnecessary dampers in the branch ducts generate more noise.

• Direct digital controls have "intelligence." A manual damper installed on the inlet side of the unit would interfere with the pressure-independent terminal unit's controller's ability to measure airflow.

• MVDs in the "high-pressure" side would increase potential leakage.

• Expensive, specialty type dampers would be needed in "high-pressure" systems.

• The equal-friction duct design has no bearing on design of pressure-independent VAV terminal units and is inconsequential.

• The government's design is contrary to recognized standards in the industry.

• For systems that reset static pressure setpoint based on VAV damper position, MVDs can increase fan energy when the VAV boxes closest to the fan have the highest loads. Furthermore, MVDs can result in starving zones with partially closed MVDs when they require near design airflow while other zones are at part load.

## "High-Pressure" Systems

The 1985 standard referenced in the contract states, "The use of the terms 'low' and 'high' as applied to velocity and/or pressure is arbitrary, and it has been discontinued. The designer must *select a numerical static pressure class or classes*…."[1] An earlier, "high-pressure" standard dated 1975 included Table 1-1 that indicated that, under the former system of classification, ductwork would not be "high pressure" until the static pressure rating was 10 in. w.g. (2.5 kPa) or higher — and it adopted these pressure classifications in the introductory text. However, the very same standard later reads, "The use of the term high velocity or the term high pressure in this text generally refers to construction requirements for any static pressure class of 3 in. w.g. or greater."[2] This apparent contradiction can be explained by noticing that Table 1-1 shows a "Seal Class" of "A" for all static pressure ratings 3 in. w.g. (747 Pa) or higher. Seal Class "A" means all seams, joints, fastener penetrations and connections are to be sealed, which ties in with the "construction requirements" verbiage (involving fabrication more than design).

### Pressure-Independent Units

The appellant's expert witness made the following argument: "A manual damper installed on the high-pressure inlet side of the unit would interfere with the pressure-independent terminal unit's controller's ability to measure airflow. It would cause excessive noise as well as additional pressure drops, which would unnecessarily increase energy consumption. It would also increase potential leakage."[3] Of course this applies to an MVD that is very close to the VAV inlet, since he was assuming the noise generated by the MVD would be louder than the noise generated by the pressure-independent VAV throttling of the air. His testimony focused on the technology of pressure-independent VAV boxes and controls, which an ASHRAE Handbook explains as follows:

"Pressure-independent systems incorporate air terminal boxes with a thermostat signal used as a master control to open or close the damper actuator, and a velocity controller used as a sub-master control to maintain the maximum and minimum amounts of air to be supplied to the space."[4]

This velocity, submaster control feature is what distinguishes a pressure-independent system from a pressure-dependent system. A pressure-dependent terminal box also has a thermostat signal controlling a damper actuator, but it supplies a different amount of air to the space as the pressure upstream of the box changes.

Although it doesn't directly address the issue of MVDs upstream of VAV boxes, an *ASHRAE Journal* article explores many myths and assumptions people have about pressure-independent controls. It covers more technical problem areas that can result, such as hysteresis in the valve actuator and pressure reset controller linkages and resulting instability. The author's thesis is that the pressure-independent feature of VAV terminals will not atone for poor air-distribution design.[5]

### Sound Level

The issue of noise is also important in these cases. Another *ASHRAE Journal* article states:

"The discharge sound power level of the VAV box in the 125 Hz octave band should be 70 dB or less… VAV boxes are available to meet these criteria, provided they are properly sized and the inlet static pressure to the VAV box is not too high. If the inlet static pressure is above 1 in. of water (249 Pa), the sound power levels will likely be too high to meet the recommended criteria. Therefore, it may be necessary to add a manual volume damper in the branch duct upstream of the VAV box to reduce the inlet static pressure to 1 in. (249 Pa) or less."[6]

This indicates that a MVD should be used upstream of the VAV boxes whenever the inlet static pressures exceeds a 1 in. w.g. (249 Pa) limit.

### Equal-Friction Method

The other peculiarity about this case is the fact that the A-E designed the VAV systems using the equal-friction method of duct design (or duct sizing), rather than using the static-regain method. These calculation procedures are the two most used supply duct design methods. The equal-friction method is typically used for low-velocity systems, i.e., less than 2,500 fpm (12.7 m/s). When this method is used, ducts are sized to have roughly the same static pressure drop for every 100 ft ( 30 m) of duct. One mechanical engineering reference manual states: "A system thus designed still will require extensive dampering, however, since no attempt is made to equalize pressure drops in the branches."[7] (However, an ASHRAE Handbook concludes its introductory paragraph on the equal-friction method by stating: "After initial sizing, calculate the total pressure loss for all duct sections, and then resize sections to balance pressure losses at each junction." [8])

SMACNA's duct design manual is perhaps the most thorough publication on the design of duct systems, but it (like

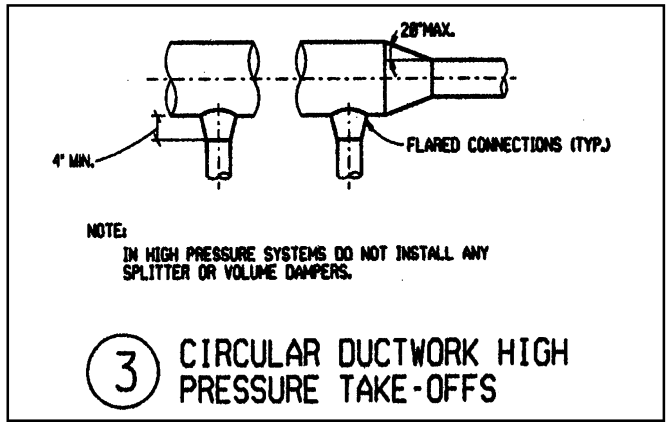


*Figure 1a: Detail 3 from the construction documents shows the note about high-pressure systems.*

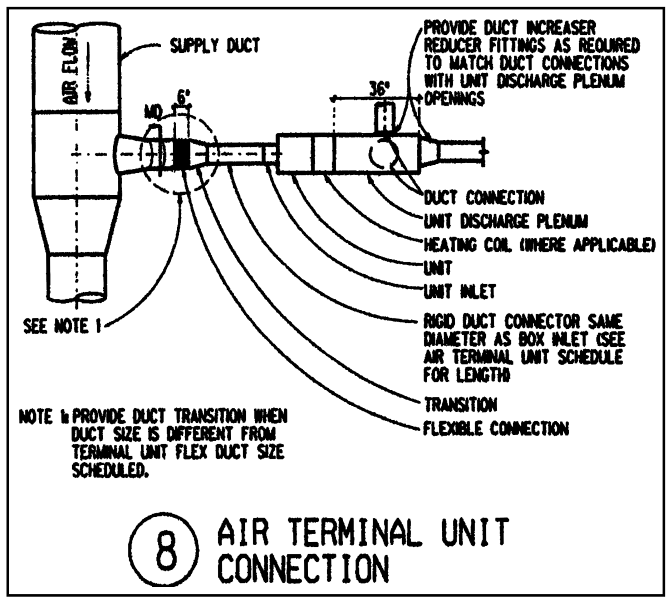


*Figure 1b: Detail 8 from the construction documents shows an MVD in the duct connection to a VAV terminal unit inlet.*

other key sources) appears to be silent on the topic of using the equal-friction method for sizing VAV systems.[9] However, according to literature published by one manufacturer, the following considerations come into play when designing supply ductwork for VAV systems using the equal-friction method:

"Static pressures throughout the duct system can be balanced at design flow using balancing dampers, but are no longer balanced at part load flows. For this reason, equal friction duct designs are better suited for constant volume systems than for VAV systems. If the equal friction method is used for the VAV supply duct design, the terminal units usually require pressure independent (PI) control capability to avoid excessive flow rates when duct pressures are high."[10]

**Static-Regain Method**

By contrast, when the static-regain method is used for VAV systems, the duct system is roughly balanced at design and part-load airflow. This is because ducts are sized to maintain uniform static pressure in each branch duct (without extensive dampering). In other words, the system can be considered self-balancing, and the inlet pressures to the VAV boxes will be nearly the same. (However, "diversity" in the system should be part of the design process, to simulate less than full load conditions to make sure the system will not get too far out of balance at partial load.)

To understand how the uniform static pressure in each branch is achieved, one must remember that total pressure is equal to static pressure plus velocity pressure. In the static-regain method, static pressure is "regained" by the conversion of velocity pressure. For a given airflow rate, a reduction in velocity pressure will result if larger duct sizes are used (although static regain can also occur with downstream duct sizes the same or smaller than the upstream ducts). Also, static pressure in a duct system is higher at the AHU. Therefore, to achieve a reduction in velocity pressure to regain static pressure to levels found near the AHU, ducts near the end of the system often have to become very large. This is a problem if the building's interstitial spaces allotted for various utilities and structural features are congested. It is important to remember that "[t]he static-regain method …can be used to recover the branch friction drops as long as the duct sizes remain reasonable."[7] (Nevertheless, to avoid spreading more misconceptions about this method, I must point out that another manufacturer's duct system design guide explains that optimizing a system initially designed using the static-regain method by substitution of small duct sizes and less efficient fittings can remove excess pressure imbalances and "virtually eliminate dampering."[11])

The static-regain method is a time-consuming, iterative, and highly theoretical calculation procedure that must be performed via a computer program, for all practical purposes, when dealing with large systems (although the equal-friction method can also be performed iteratively via computer software). "It is generally a good idea to install dampers even when more sophisticated design methods are used. Such dampers can be used for fine-tuning the installation."[7] ASHRAE goes even further on this last point, "Dampers must be installed throughout systems designed by equal friction, static regain, and the T-method because inaccuracies are introduced into these design methods by duct size round-off and the effect of close-coupled fittings on the total pressure loss calculations." [8]

## Relevant Legal Theories

A few of the relevant theories from contract law are:

- Contracts must be read as a whole and the parts harmonized if at all possible.
- Patent (glaring) ambiguities impose a duty to inquire pre-bid in order to recover damages.
- Latent (concealed) ambiguities will be construed against the drafter of the contract.
- An Appellant will often prevail if it can show its interpretation was "reasonable."
- Contractors can attempt to rely on the "trade usage and custom" of terminology.
- The 'Order of Precedence' clause states that the specifications govern in the case of a conflict between the plans and specifications.
- The Government is entitled to strict compliance with the contract's requirements without regard to whether the contractor believes that it is prudent or desirable.
- An Appellant must show that it relied upon the subcontractor's interpretation at the time of bid submission.

**Testing & Balancing**

The national standards published by the Associated Air Balance Council (AABC) contain figures showing HVAC components for various types of VAV systems. Both Figures 19.2 and 19.3 for single duct, pressure-dependent and pressure-independent VAV systems, respectively, show manual opposed-blade balancing dampers upstream of the VAV terminal boxes.[12] It was noted at the trial that, in the AABC illustrations, the pressure-dependent system has dampers shown both immediately upstream of the box and further upstream, whereas the pressure-independent diagram shows a volume regulator sensor immediately upstream of the box and a damper further upstream where a branch duct comes off of a main duct. Nevertheless, this bible of the Testing and Balancing industry clearly indicates a manual damper in the ductwork between the AHU and a typical pressure-independent VAV box.

## Reducing Energy Consumption and Noise

According to an article by the president of a damper firm, static pressure that must be overcome by the fan is the "biggest thief of energy in an HVAC system." He further states: "But there is one static-reducing technique that is not often used — using MVDs at points where you want to reduce the static pressure, velocity pressure, and sound all in one. By installing MVDs in the proper location prior to the VAV boxes (variable air volume), this can be achieved."[13]

The author of the article points out that the VAV boxes closest to the AHUs are almost closed in the full cooling mode, and create noise. This is because it takes a high static pressure at the fan to be able to deliver the required airflow to the farthest VAV box in the system. "By simply installing a MVD at the takeoffs from the main duct to the branches that serve each of these VAV boxes, you can instantly and efficiently reduce the wasted static pressure that is traveling down all these additional runs and creating all these problems and wasted costs."[13]

He also cites a 15% to 25% savings in total energy consumption. He explains that this is achieved because MVDs divert excess airflow at the boxes closest to the AHUs downstream with no waste, and the reheat coils have a very even and efficient heat transfer when design airflows are present at the VAV boxes. The reduction in energy consumption is the direct result of the reduction in the speed of the fan, which follows from the preceding air balancing (to design criteria) made possible by MVDs.

His article also explains the theory behind the noise reduction benefit: "By reducing the static pressure at the branch coming off the main duct, we allow the damper in the VAV box to open further, yet deliver the same quantity of air. This eliminates the jet velocity, which reduces the noise off the damper blade in the VAV box."[13] (Of course, at the same time it creates more noise at the location of the MVD. Whether one noise source or two is better depends on the location of the VAV box and damper relative to noise sensitive spaces.)

One could read the above and think it doesn't make sense, and that this author is clearly a supplier of dampers trying to sell more dampers. However, there is a sense in which he would be correct, and it's worth explaining for clarification.

The fan energy is going to be dictated by the airflow, and the pressure required in the critical path. He probably means that if the critical path is not getting the required airflow, the fan pressure would have to be increased until it does. This requires much more horsepower because the increased airflow and static causes even more air to go to non-critical paths. Whereas, if the systems were balanced, the fan would only need to produce the static required for the critical path. (Counter-argument: The pressure-independent VAV boxes ensure that the required airflow is not exceeded in the close branches.)

## Conclusion

This article has hopefully brought this issue into the light and may stimulate further debate and scientific investigation. Several "lessons learned" and opposing viewpoints from the

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cases have been presented from both legal and technical perspectives. Also, several references on related topics have been thoroughly examined. The excerpt from the *2001 ASHRAE Handbook—Fundamentals* indicates that MVDs should be provided throughout systems, regardless of which design method is selected. In this particular application, there are definitely differences in opinion.

For example, it has been argued that, had the system been properly designed using the T-method and optimized with excess pressures of less than 10% of the pressure required to operate the critical path, the VAV boxes would have easily been able to handle any small discrepancies in airflow rate without becoming excessively noisy. (These are the procedures alluded to earlier that would possibly have made this a moot debate.) However, that argument assumes the system will be constructed in accordance with an optimized design, without any duct size round off or substitutions of fittings in the field. Nevertheless, one can argue that the specifications should require a balancing report showing the static pressures at the VAV boxes; and, if the contractor alters the design, it must show (through a revised computer run) how the changes affect the system.

Finally, in reference to the above argument, I will concede that properly designed systems are those that minimize owning cost, are balanced and have acceptable noise levels. However, the government's A-E design firms were required to perform a life cycle cost analysis, and they generated reams of computer-generated design reports that were reviewed by multiple teams of professional engineers, along with the drawings showing the MVDs. The equal-friction method selected by the A-E was questioned during the review process because these were VAV systems, but the reasons given for its use were accepted. In this actual case, the superfluous "high pressure" note on one drawing detail and the uncommon practice of showing MVDs just upstream of pressure-independent units led to litigation, and more definitive and unambiguous design/application guidance dealing with the peculiar circumstances mentioned in this article would have been beneficial. Therefore, give all of this careful consideration!

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