OPTIMUM VENTILATION AND AIR FLOW CONTROL IN BUILDINGS

17th AIVC Conference, Gothenburg, Sweden, 17-20 September, 1996

COMPUTERISED METHODS FOR BALANCING VENTILATION SYSTEMS

Bjørn Tore Larsen

The VEKST Foundation,
Oslo, Norway

OPTIMUM VENTILATION AND AIR FLOW CONTROL IN BUILDINGS

**17th AIVC Conference, Gothenburg, Sweden,
17-20 September, 1996**

COMPUTERISED METHODS FOR BALANCING VENTILATION SYSTEMS

Bjørn Tore Larsen, M.Sc., MASHRAE,
The VEKST Foundation,
Oslo, Norway

SYNOPSIS

Adequate ventilation with the "right amount of air, to the right place and at the right time" are important factors for achieving a good indoor climate. Thus it is of prime importance that the ventilation system is working properly. Using traditional methods, it is a very time consuming, and some times even impossible, task to balance ventilation systems to achieve correct air distribution. In most countries the growing concern about Indoor Air Quality has resulted in Building Codes demanding increased ventilation rates. This makes it even more critical that ventilation systems are correctly balanced. Otherwise the effort of solving one problem: "inadequate ventilation", may create two new problems: "draught and noise".

This paper describes the "DPM method" which is a new method for balancing ventilation systems. The balancing "starts at the designer's desk" by doing a comprehensive computerised pressure loss analysis. The results from this analysis are then input to a PC connected with an electronic instrument. The PC/instrument may be used for balancing when the air terminals are already installed in the building. However, there is a much larger potential for time and cost savings when using the DPM method for pre-setting air terminals at the factory. For this purpose a "DPM machine" has been designed for computerised pre-setting and bar code labelling of air terminals.

With impressive results the ventilation systems in a number of buildings have been balanced in the last two years using the described innovative technology.

VEKST\INTEK\ADM\aivc.pap

1. BACKGROUND

Sponsored by the Norwegian Research Council (NFR), three years ago the VEKST Foundation started developing a new method for balancing ventilation systems. It was based on the philosophy that "balancing starts at the designer's desk". I.e. from the very start the designer should have in mind how to balance the system. A necessary tool in this phase of work is a good computer program for duct design and pressure loss analysis. Such a program will give a complete picture of necessary pressure drop in dampers and air terminals in order to give design air distribution.

Even today, with the computer being a common inexpensive tool, many engineering consultants and contractors still consider making computerised pressure loss calculations of the ductwork a more or less "academic exercise" of little practical value. Being the supplier of a well known Norwegian duct calculation program we certainly do not agree with this opinion. But we felt that we had to do something in order to make duct analysis more attractive, e.g. by making the calculated result directly applicable for the final balancing of the system. We came up with a solution based on recent technological development of computers, electronics and ventilation equipment:

* The Personal Computer has become an inexpensive common tool for most engineers. High computer costs are no longer an excuse for not making pressure loss calculations.

* There are many computer programs for doing pressure loss calculations available on the market. Tests have proved that results from well known programs differ very little from actual measurements.

* Reliable electronic pressure transducers are available that makes it very simple to measure the low air pressures that occur in ventilation systems. The readings are easily presented on a display or as an analogue electrical signal.

* Dampers and air terminals are frequently equipped with a differential pressure device for measuring the air flow.

As can be seen, the prerequisites for designing and balancing duct systems in a more "engineering way" is now a reality. In the following a new method for balancing ventilation systems, the "DPM method", will be presented .

2. THE DPM METHOD

Any air terminal or damper has, for a given adjustment, a unique pressure loss characteristic. In ventilation systems the flow is usually turbulent, and in that case the relationship between air flow and pressure loss can be expressed as:

Average exponent in HVAC = 1,9
Smooth duct = 1,7

$$P_t = k_1 Q^2 \quad \text{or} \quad Q = k_2 \sqrt{P_t} \qquad (1)$$

Where: P_t = total pressure loss Q = air flow k_1 and k_2 = constants

Figure 1 shows Eq. 1 for a damper in three different positions. Imagine that a pressure loss calculation has shown that the damper must produce a pressure loss P_{nom} when the required air flow is Q_{nom} (point 1). The constant **k** is found by using P_{nom} and Q_{nom} in Eq. 1 and solving for **k.** If the damper is fixed in the correct position, air flow and corresponding pressure loss will follow the parabola through point 1. This parabola is the pressure loss characteristic of the damper in that position.

If you have equipment that "tells you" when you are on the desired pressure loss characteristic, air terminals and dampers can be given the correct adjustment even when the air flow is far off from the desired, or nominal value, for instance point 2 in Figure 1. This is what the DPM method is all about: **"finding the correct pressure loss characteristic", or k-value, for air terminals and dampers.**

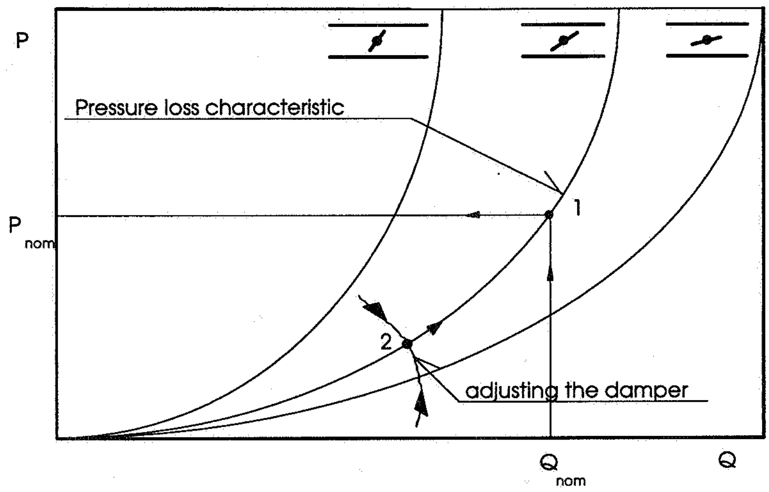

Figure 1 Pressure loss characteristics of a damper in three different positions

3. ELECTRONIC EQUIPMENT

By using two electronic pressure transducers and an "A/D-converter" connected to a PC with a standard RS-232C cable, it is possible to find the pressure loss characteristic of air terminals and dampers. Figure 2 shows one possible way of doing this. The differential pressures for both the air flow measuring device and the flow resistance are measured simultaneously. The fact that to differential pressures are measured is the reason for the name "DPM Method" (Dual Pressure Measurements). Certainly the optimum situation for using the DPM method is when the air flow measuring device is an integral part of the equipment, but that is not a requirement.

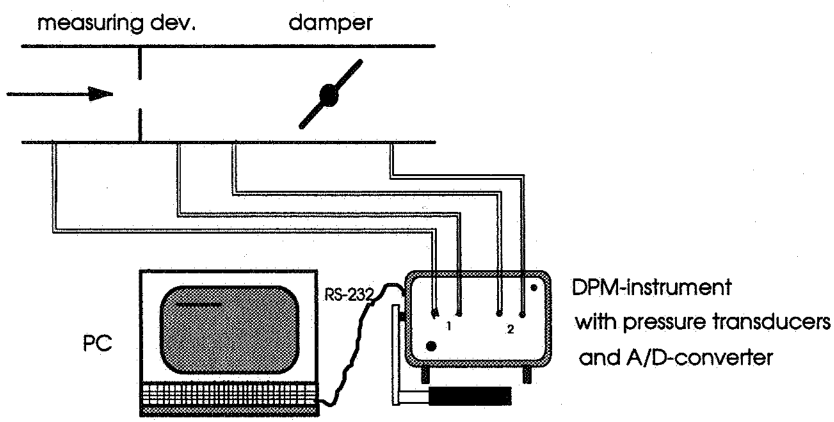

Figure 2 The principle of the DPM Method

When adjusting the air flow through the air terminal/damper the two pressure differences are measured continuously (1 - 2 times per second) by the program running in the PC. The program calculates the k-value of the momentary pressure loss characteristic and compares it with the desired k-value. When the correct k-value is reached, the PC informs you of that by giving a high pitch beep.

The DPM method allows you to adjust the damper or air terminal without having to bother to much about the magnitude of the air flow. Tests have shown that the adjustments may be done with the air flow as low as approx. 30 % of the design air flow. The lower limit is due to the danger of getting laminar air flow.

4. APPLICATIONS

Originally it was assumed that the main application of the DPM method would be for adjusting air terminals and dampers after they have been installed in the building. I.e. using the DPM Method as an alternative to other methods of balancing. Because the air flow at the time of balancing is of little importance, it is possible to do the balancing *before* the ventilation system is completed. For instance it is possible to balance a floor by hooking up a transportable fan to the ducts system of that floor.

The next logical step is to pre-set the air terminals or dampers in advance, i.e. at the factory before they are shipped. The goal of a present project is to develop the necessary procedures and tools for doing this is . The project is a development contract with the Norwegian Defence Construction Services (FBT), The Norwegian Industrial and Regional Development Fund (SND) in co-operation with Auranor A/S, a major Norwegian manufacturer of ventilation equipment. Figure 3 shows a computerised machine for pre-setting air terminals which will be installed at the factory. The machine consists of a small fan, a device for measuring air flow, a DPM-instrument, a PC, two printers and some pieces of ductwork. The ducts which are connected to the air terminals being pre-set are easily exchangeable. Tests made with a prototype of this machine shows that it is quite easy to adjust an air terminal to the required pressure loss characteristic in less than 30 seconds.

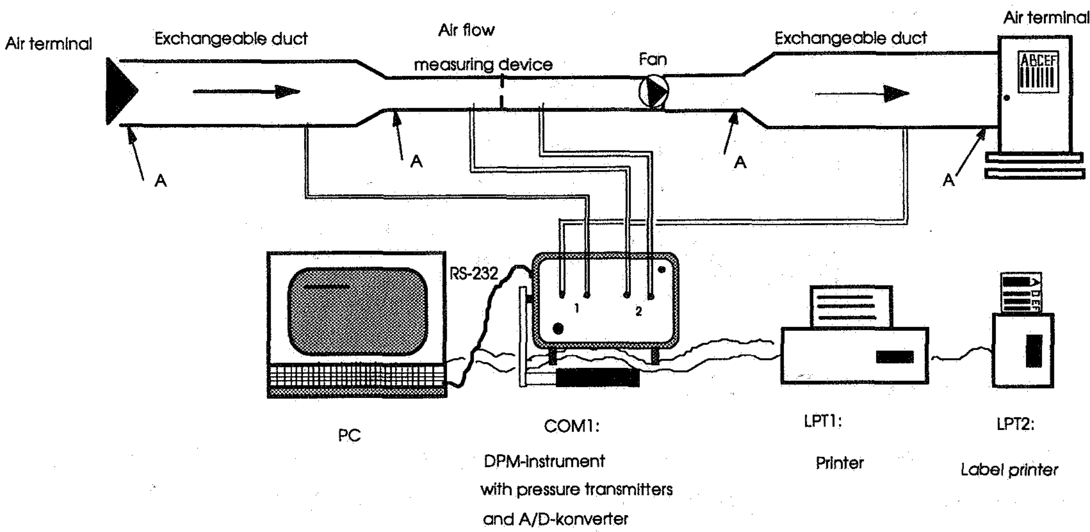

Figure 3 A "DPM machine" for pre-setting air terminals

At the same time as the setting is done, labels are printed to identify the correct location of the air terminal in the building. Two labels are attached to each terminal. One of the labels is human readable telling the installation people where to install the air terminal. It is put on a place that makes it non-visible after installation. The other label, which is quite small and has a bar code, is visible after installation. Thus, using a bar code reader connected to a portable PC, it is quite easy to check that an air terminal is installed in it's right place when doing the final control.

With the air terminals pre-set as described above, the physical balancing process will be reduced to making control readings of the air flows and doing some minor adjustments for a few terminals. In order to speed up this process, as well as giving a good documentation, a new PC-based instrument has been developed. It consists of 8 pressure transducers and an A/D converter connected to the serial port of the PC. The instrument makes simultaneous pressure readings of the air flow measuring devices of 8 air terminals.

The 8 readings are shown on the PC screen as "living columns" showing the *relative air flows*, i.e. actual air flow divided by design air flow (%). When the relative air flows are equal, the air terminals are balanced with respect to each other. By adjusting the damper for this branch of the ductwork and/or adjusting the speed of the fan, the correct absolute air flow is established.

Usually there are more than 8 terminals in a branch. In this case one starts with the 8 terminals farthest away from the fan. When they are balanced with respect to each other, the next 7 air terminals are connected to the instrument with one of the terminals in the previous group still connected to the instrument. The 7 terminals are then adjusted to give the same relative air flow as for the one still connected with the terminal in the previous group. This way you work your way through for the whole branch. By using this technique of always having a connection to one of the air terminals in the previous group, all of the terminals in the branch will end up having the same relative air flow as the last group of terminals that was balanced (the "proportional principle").

Each time a group of air terminals is balanced the result is saved to a disk file in a format that is accepted by common spread sheet programs (Lotus, Excel ..). This way it is easy to produce the necessary dokumentation of the work being done.

5. EXPERIENCES

In the past two years VEKST has been balancing ventilation systems in a number of buildings using the described innovative technology. Most of the buildings are buildings where it is of prime importance that the air distribution is correct. E.g. hospitals, laboratories (clean rooms), defence installations and some prestigious office buildings.

More than 3000 extraction air terminals has been pre-set using the DPM method. When controlling the air distribution after installation, it is found that less than 5 % of the terminals need to be adjusted. Pre-setting of supply air terminals is now being tested in the present project. Preliminary tests show that we can expect equally good results as for the extraction air terminals.

The principle of the DPM method may also be applied to hydronic systems, but we have no practical experiences so far.