TECH TIP # 24

HEATING, AIRCONDITIONING & REFRIGERATION DISTRIBUTORS INTERNATIONAL

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Extended Plenum Problems?

Ever confronted by this one? More air comes out the far branch registers than from those closest to the furnace. Balancing a system is never easy. And sometimes it can be frustrating -- unless you understand why the air behaves the way it does. Here's a short rundown on balancing peculiarities of extended plenum type duct systems.

Theoretically, truck-duct supply systems can be made "self balancing"; that is, duct work can be sized to impose the correct resistance along the system's path so that the desired air flow is diverted through each branch and delivered to each room. Of course, in reality some balancing with dampers is usually needed. On the other hand, an extended plenum system is far from being self-balancing; considerable dampering is very often needed. And surprisingly, the complaint often heard is that *less* air comes out the branch ducts *nearer* the furnace and more air is delivered out of the *furthest* runs.

Actually, this apparent paradox is readily explained. It's all concerned with the branch takeoff fittings and the momentum of the moving air stream.

The curve in Figure 1 shows the pressure loss -- in terms of equivalent feet of straight duct -- for the common type of streamline side takeoff fittings used on extended plenums. The loss is related to the ratio of the air velocity in a branch (V_b) divided by the air velocity in the plenum (V_p) just upstream of the fitting. This velocity ratio is really a measure of the momentum of the two (branch and plenum) moving air streams. What does the graph tell us?

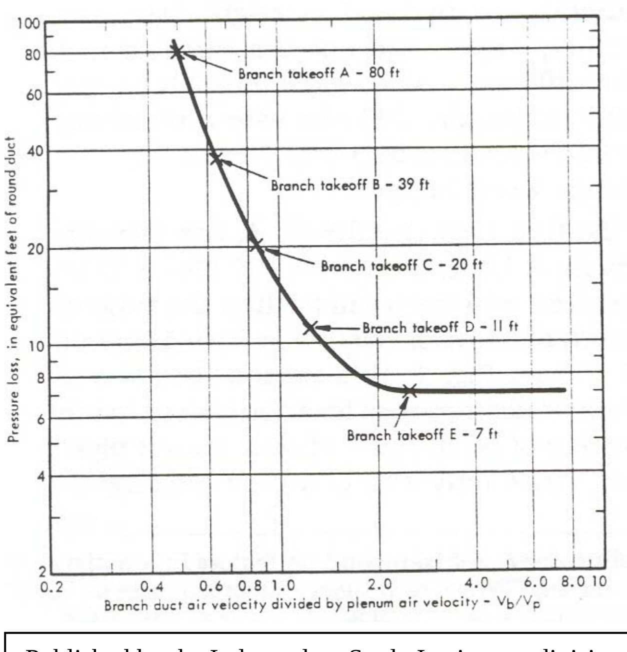

Figure 1. SIDE TAKE-OFF fittings, used to link branches to an extended plenum, do not have a constant value pressure loss. Loss depends on branch and main air stream velocities as shown by curve.

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The shape of the curve tells us that the higher the plenum velocity in relation to branch velocity, say V_b/V_p, less than 1, the greater the fitting pressure loss. That is, it becomes harder to turn air 90 degrees from the main to the branch as the air in the main moves faster. Conversely, as the plenum velocity is lowered, again relative to the branch velocity, the slower air stream can be turned more readily and the fitting loss is reduced.

Fittings Closest to Furnace Have Greatest Loss

Consider what effect this has on the system. Suppose we have installed a furnace system fitted with a 9 inch wide x 8 inch deep extended plenum, say about 20 ft. long on one side of a furnace. About 500 cfm is discharged into the plenum from the furnace. Connected to the plenum are five 6 inch round branches. (See Figure 2)

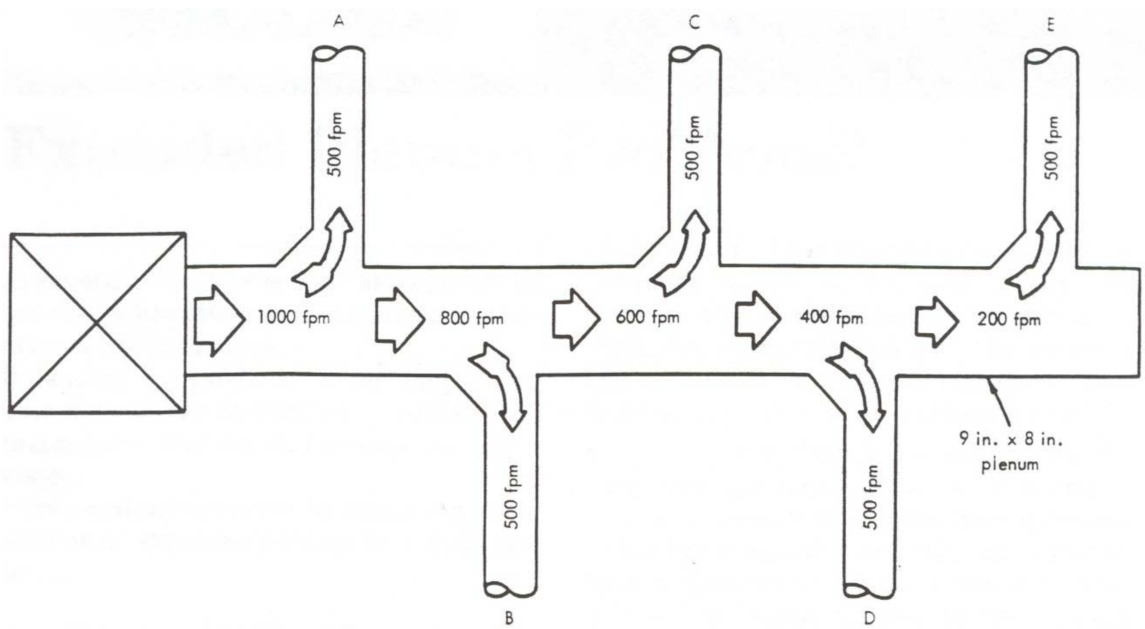

Figure 2. An EXTENDED PLENUM. Unlike a reducing truck duct, is a constant size along its entire length. As air is diverted out succeeding branch runs, the velocity of the air remaining in the main decreases. Thus, the air initially has greater momentum and it can be harder to turn into a branch duct.

These branches are identical in length, have the same type boot, and use the same size of floor diffuser. Also, each branch is expected to handle 100 cfm with a resulting duct air velocity of 500 fpm. Here's why this balance won't happen.

At the first branch take-off, *A*, the plenum velocity is 1000 fpm and if 100 cfm is to be extracted into the branch, then the ratio of branch to plenum velocity is 500/1000, or 0.5. From Figure 1, this means the take-off fitting would impose a loss equivalent to the addition of 80 ft. more of 6 inch round pipe. Next, since only 400 cfm now remains in the plenum, the air velocity in the main drops to 800 fpm. Then, the conditions at take-off *B* are: branch velocity, 500 fpm; main velocity, 800 fpm; resulting in a velocity ratio of 0.63. Again, from Figure 1, the take-off fitting at *B* would impose a smaller resistance equal to 39 ft. of pipe. This same situation repeats itself at *C*, *D*, and *E*. The velocity in the main decreases after each branch and the succeeding fitting losses are less.

The last fitting, E, for instance, would impose a loss equal to only 7 ft. of pipe. We have illustrated these conditions diagrammatically in Figure 3.

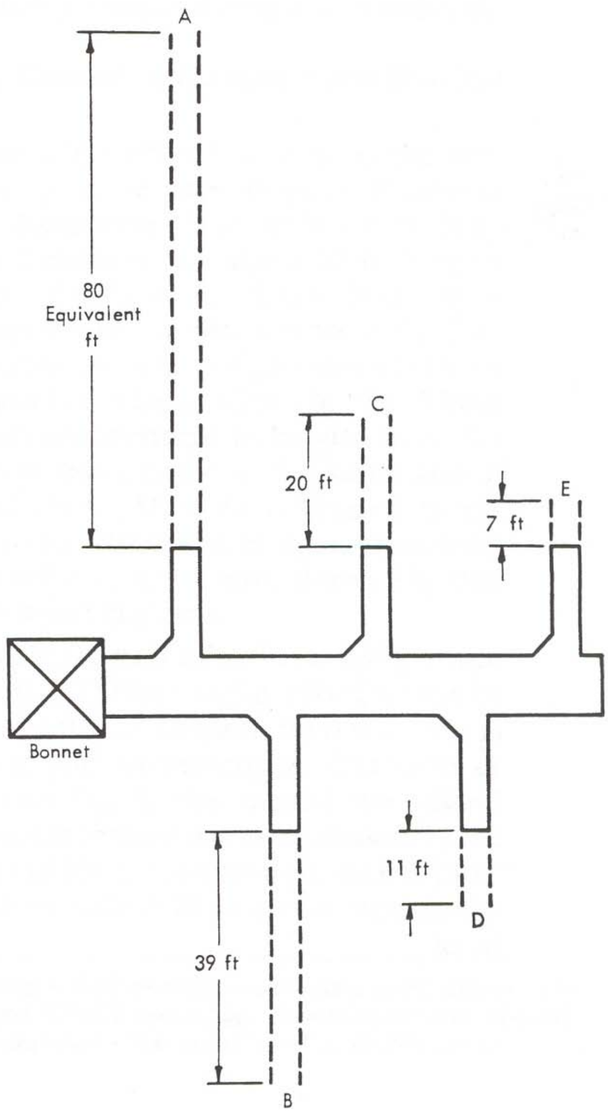

Figure 3. EQUIVALENT LENGTH of take-off fittings when added to the actual duct length makes the closest branch the longest run in terms of resistance to air flow. Result: first branch delivers less air than last branch.

The dotted lines symbolize the added resistance due to the take-off fittings. At this point, let's remember that the pressure from the furnace bonnet to the exit of each branch duct must be the same. If the pressure at the bonnet is, say, 0.15 in. WG, then the loss from the bonnet to exit A is 0.15 in. WG and the loss from the bonnet to exit *B* is also 0.15 in. WG, etc.

Flow Adjusts to Equalize Pressure

In order for the losses to be the same in our case, the air flow through each branch will vary according to the length of each run. And since the total equivalent length from the bonnet to the exit at branch *A* is greater than the total equivalent length from the bonnet through the outlet on branch *E*, more air will flow out branch *E* than branch *A*.

It is possible, then, that only 50 cfm will flow through branch *A* and 150 cfm will flow out branch *E* -- with corresponding proportions between the other branches.

Thus for our case, the branch physically closest to the furnace actually handles less than the desired air volume, while the branch furthest away delivers more than desired. (These exact extremes are not always true.)

In practice, dampers would be used to add resistance to branch *E* in order to cut down the air flow rate in that branch and help divert more air out branch *A*. At times, extractors might also be used at branch *A* to literally scoop the proper air volume into the branch. Dampers and the like, of course, add resistance to the system and mean more work for the fan and can raise the noise level as well. Besides, even these aids can fail when plenum velocities are too high and branches are placed too close to the furnace; then, under these circumstances changers have to be made to the system. It's best to design right, right from the start.

For conventional systems, good practice indicates that main ducts should be sized so that air velocities do not exceed 900 fpm for residences, 1300 fpm for commercial buildings, and 1800 fpm for industrial plants.