# Myths and Facts about Vacuum Systems by Steve Brandt

Never in recorded history has any subject been discussed as much, and understood as little, as vacuum systems and their effects on carpet cleaning. It's really no wonder that confusion reigns when you really study the often misunderstood complexity of vacuum theory. As a result, our industry has spawned many schools of thought interspersed with facts, myths and legends of what vacuum systems can accomplish.

Striving for perfection, many carpet cleaners find themselves on a quest for even better cleaning. As a result, they find themselves vulnerable to claims of a vacuum system's capability which go beyond the real world and the physics involved. Don't fall into believing that there is any magic involved, and don't be vulnerable to "vacuum mystique."

In arming yourself to be a better buyer, let's talk in terms of "Conventional Wisdom," or C. W. There follows a very simplified and basic explanation of the C. W. in the science of pneumatic conveyance through the use of vacuum. That's right, what we are trying to do when we clean a carpet is recover water (with soil, etc.) and convey it through the use of air (pneumatically).

The following is designed to familiarize you with four basic factors concerning vacuum systems: Lift, Airflow, Velocity and Friction Loss. The interrelationship of these factors is complex, but important.

Lift: This is one factor of vacuum which is easily seen and measured because you can simply read it on a gauge. The gauge measures the lift, or vacuum level, in one of two ways: 1) Inches of water lift, or 2) Inches of mercury lift. Simply two different ways to say the same thing. Mercury (Hg) is heavier than water so, 1" of Hg= 13.5" of water. In other words, 10" Hg is the same vacuum level as 135" of $H_2O$ lift. Since it is the only reading a carpet cleaner typically has available to him, it tends to be the most misunderstood.

**Myth #1**: The more lift a system has, the better the cleaning will be.

To illustrate why this is a myth, try the following. Put a marble on a table, take your vac hose cuff and place it over the marble, sealing the cuff on the table. Now have someone start your machine. The vac gauge will show its highest lift because of the seal, but the marble hasn't moved. Now crack the seal of the cuff and let in some air. Even though the gauge shows a drop in lift, the marble races down the hose due to the airflow.

Airflow: This factor takes into account the volume of air being displaced in a vacuum system. Airflow is usually expressed in cubic feet per minute or CFM. Since the moving air will carry (pneumatically convey) the waste and soil back through the hoses to the recovery tank, the airflow is a key factor. There isn't an easy way for the cleaner to measure the CFM of a cleaning system. But, the easiest way to compute airflow, is to refer to the performance curve of the system, made available by the manufacturer of the primary air pump. At any given level of lift, you can refer to the curve and read the corresponding CFM.

**Myth #2:** The more CFM a vacuum system has, the drier the carpet will be after cleaning.

The CFM figure can't be evaluated alone, any more than the lift figure can. The following shows why:

Lift vs. Airflow: These two factors are interdependent. They are tied to one another; if one goes up, the other goes down. This is called an inverse relationship. To illustrate this, refer to the chart in Figure 1. Let's suppose that when you look at the vacuum gauge of your truck mount the reading is a level of 6" Hg. Looking at chart 1, we see that at this level of lift, the system is capable of moving about 175 CFM.

Now suppose you do something to the system such as add more hose or improve the wand seal. Now your gauge reads a level of 10" Hg. From the chart, you can see that you now hit the performance curve at point "B" and that the airflow has dropped to about 150 CFM. So, as one factor (lift) went up, another (airflow) came down. They have an inverse relationship. Fact: The most effective cleaning is accomplished when there is <u>proper balance</u> between lift and airflow.

Air Watts: There is a way to quantify and predict where the "sweet spot" of a vacuum performance curve lies. The computation of air watts takes into account the effects of both factors. This gives you the best combination of lift and airflow: Formula: Air Watts = Lift x CFM divided by 8.5. Using this formula to calculate the values in Figure 1, you will see that Point A yields 123 Air Watts (6 x 175 divided by 8.5) and Point B yields 176 Air Watts (10 x 150 divided by 8.5). Computed for our sample points from Figure 1, you can see that Point B is a better point at which to operate our equipment because the available "work energy," measured in air watts, is greater.

Velocity: This factor is an expression of the speed at which air is moving at any given point in the vacuum system, expressed in feet per minute (FPM). The airflow factor above already told us how much air is moving, but the velocity will depend on the size of the tube the air is moving through. There is a linear relationship between airflow and velocity. As one goes up, the other goes up directly. If you know the airflow CFM and the size of the opening it is passing through, you can then compute the velocity as follows: Formula - Velocity (FPM) = Air Flow (CFM) divided by tube area (sq. ft.).

In order to do good cleaning, we need a certain minimum velocity or speed of air, in order to suspend water and keep it moving after it is suspended. Too little velocity at any point in the system will cause the water to fall out of the air stream. Figure 2 shows air velocity, computed for various air handling locations in a cleaning system.

| Figure 2: Velocity (FPM) with Variable Openings and Airflows | | | |
|---|---|---|---|
| | AREA ($Ft.^2$) | AIRFLOW | |
| | | 150 CFM | 175 CFM |
| CONVEYANCE:<br>1 1/2" Dia. Vac. Hose<br>2" Dia. Vac. Hose | <br>.0123<br>.0218 | <br>12,195 FPM<br>6,881 FPM | <br>14,228 FPM<br>8,028 FPM |
| PICK UP POINT:<br>11" Wand Slot (sealed)<br>14" Wand Slot (sealed) | <br>.0064<br>.0081 | <br>23,438 FPM<br>18,519 FPM | <br>27,344 FPM<br>21,605 FPM |

Note that the chart is broken down into two areas: 1) The conveyance points, or the hoses and tubes: 2) The pickup point, or the wand slot. Conventional Wisdom in engineering calls for a velocity of at least 5,000 FPM to convey water efficiently. You can see on the chart that this speed is easily achieved in the hoses if we move enough air. But why is the air velocity so much higher at the wand slot (pickup point)?

The slot velocity must be higher so that water is picked up even at some distance from the slot, so an "aura" of air movement is created around the wand slot to improve water recovery. If the velocity were lower, water would have to be right in the slot in order to be picked up. As such, depending on how much air we are moving, the necessary water pickup velocity is achieved at further and further distances from the slot and water is recovered more aggressively.

**Myth #3**: The more air velocity a vacuum system has, the "better" the system.

At some point the law of diminishing returns comes in, and it takes massive increases in power to achieve any small amounts of benefit. We also begin to encounter more and more friction loss.

Friction Loss: All the numbers we've discussed thus far, assume ideal conditions, with the vacuum pump not subject to any restrictions. That's not how it happens in the real world. When we put a silencer on, we get back-pressure. When we run the air through pipes and elbows and long vacuum lines, it produces restriction. If the vac tank air filter is too small or clogged, it restricts greatly. All these losses are due to friction along the walls.

The friction loss in any tube directly varies as the velocity varies. There is a linear relationship. As the velocity increases, your friction loss increases. A practical example of this can be seen with vacuum hose. Note in figure 2 that the air in a 1 1/2" hose travels at a velocity roughly twice as fast as the air travels once it reaches a 2" hose. Since friction loss goes up with velocity, it follows that there is roughly twice the vacuum loss in the small hose than in the 2" hose. These losses rob available vacuum power from your cleaning.

What conclusion? It's all just good theory so far. The practical effect all of this theory has on the design of effective cleaning systems is the subject of another presentation. Hopefully, one thing is clear -- vacuum science is complex and interrelated, and must be considered as a dynamic whole. To simply ask how much lift or CFM a cleaning unit has in only the tip of a gigantic iceberg. -- unless you know the rest of the story