Roof Vent Brief Review

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1 Introduction

1.1 Report Scope

This report will provide a comparison of the VADA Vent and two other roof vent designs, based on simple models and first principles. The calculations will not take into account inlet, outlet, or internal geometries.

1.2 Review Team

Alexander Glew, Ph.D., P.E. and Alexander Kahler, M.S. wrote this report.

1.3 Overview of the vent systems

The purpose of these vent systems is to help secure roof membranes to the top of a building by equilibrating the pressure between the membrane and the building with the pressure above it. High winds can tear membranes off roofs if either a gust lowers the air pressure above the membrane or air infiltrates beneath the membrane and increases the pressure there. Thus, it is important to rapidly equalize any increase in pressure underneath the membrane, in order to keep it in place.

The VADA Vent uses a familiar “whirlybird” turbine to derive power from wind blowing in any direction. This turbine spins a series of fans in the duct beneath it, which actively pull air from beneath the membrane. By creating a negative differential pressure underneath the membrane, compared with atmospheric pressure above it, these vents ensure that the membrane stays attached to the surface. The suction created has the secondary benefit of holding the vent system to the roof, even in high winds.

The other vents reviewed in this report perform similarly, but rely on the Venturi effect to create negative pressure, rather than the VADA Vent’s moving parts. The Venturi effect describes the increase in fluid speed and decrease in fluid pressure that result when that fluid flows through a constricted volume. The shape of each of these other vents creates a narrow path for wind to flow through, which decreases its pressure. An opening on the narrow path connects it to the air beneath the membrane, so that the lower pressure in the path pulls that air out, equalizing the pressures above and below the membrane. The second vent is shaped somewhat like a mushroom, bringing air in and out underneath the “cap”. The third vent is comprised of two domes facing each other, in order to compress the wind between them and increase its speed. As before, the suction created by both vents holds them to the roof.

1.4 Theory/Thesis

For all of these vent systems, the primary function is to equalize pressure beneath the membrane and above it. While the suction that holds these vents to the surface also provides some small measure of securement for the membrane, it is not enough to hold the membrane’s entire roof area on its own. Thus, pressure equalization is the final goal, and we can say for all vents that the initial state of the system is high pressure beneath the membrane and the final state is equalized pressure. The remaining variable to compare is the time it takes for each vent to equalize the pressures. If we consider three roofs of the same size, each with one of the vent systems installed, then the vent system that more rapidly removes over-pressured air from the volume underneath the membrane should be superior in a high-wind situation.

2 Mathematics

2.1 Minimum cross sectional areas

For calculating the limiting flow rates, we need the minimum cross sectional areas for each vent. The VADA Vent has a single 6" diameter throat, giving a cross section of 28.27 in^2. The second vent ("mushroom") has a similar 6" throat, giving the same 28.27 in^2 area. The third vent ("domes") has a much different shape, and its minimum cross section is located where it moves air through three tubes, each with a measured inner diameter of 0.615". This results in a much smaller cross section of 0.891 in^2.

2.2 Pressure inside the vent

For the purposes of comparing the performance of these vents, Vada LLC contracted another firm to construct a small wind-tunnel device. Each vent was bolted down in front of the wind outlet, with a ¼" tube connecting the inner volume of the vent to a pressure sensor. The test was performed on all three vents, and the internal pressure for each vent was measure for comparison. The VADA Vent produced a differential pressure of 13.5 pounds per square foot (psf), the "mushroom" vent 3.1 psf, and the "domes" vent 26 psf.

2.3 Volumetric flow rates

The Bernoulli principle, shown in equation (1), allows one to calculate equivalent energies for fluid flow at different points in a system. For our calculation, we will use the form

$$\frac{1}{2}\rho_o {v_o}^2 + \rho g z_o + P_o = \frac{1}{2}\rho_f {v_f}^2 + \rho g z_f + P_f \qquad (1)$$

where

- ρ_o = initial fluid (air) density
- ρ_f = final fluid (air) density
- v_o = initial fluid velocity (the air is initially at rest)
- v_f = final fluid velocity
- z_o = initial fluid height, z_f (very small change, neglect for gas)
- P_o = initial pressure (atmospheric)
- P_f = final pressure (inside the vent)
- g = acceleration due to gravity

Solving equation 1 for v_f yields the equation:

$$v_f = \sqrt{\frac{2}{\rho_f}(P_o - P_f)} \qquad (2)$$

where $(P_o - P_f)$ is equivalent to the differential pressure.

Using the pressure values from section 2.2, we use equation 2 to calculate the following:

	Differential pressure inside vent (psf)	Minimum cross section (in^2)	Air velocity (in/s)	Volumetric flow (in^3/s) [cfm]	Flow ratio, compared to VADA
VADA Vent	13.5	28.27	1,285	36,320 [1,261]	100%
"Mushroom" vent	3.1	28.27	643	18,180 [631]	50%
"Domes" vent	26	0.891	1,788	1,590 [55]	4%

We calculated the flows using the Bernoulli equation (1), using the pressures cited in §2.2 taken at 150 mph. These flows are extremely high and represent idealized flow in a nozzle with 100% efficiency. In reality, the values would be lower, and one could determine them more accurately from computational fluid dynamics or testing.

Though the “mushroom” vent has the same cross sectional area as the VADA Vent, it generates less than one quarter of the pressure. As a result, the VADA Vent will evacuate air twice as fast as the “mushroom” vent. Furthermore, the low pressure generated within this vent will also provide less securement for the vent structure itself, increasing the chance that high winds might blow it away.

Although the “domes” vent creates a larger pressure differential, the tiny cross sectional area of the three tubes cannot match the large throat of the VADA when it comes to volumetric flow. For any given roof membrane, the VADA Vent will evacuate over-pressured air approximately 23 times faster than the domes vent.

These values are the initial rates at the start of a gust; velocity and flow rates will decline as pressure differential equalizes. This applies to all three vents, however, so the volume flow rates of the “domes” and “mushroom” vents will always be significantly less than that of the VADA Vent. Furthermore, Bernoulli’s principle shows that fluid velocity is proportional to the square root of pressure. Since the “domes” vent starts at a higher pressure differential, during equalization the pressure differential will drop faster than it does in the VADA. Thus, for the “domes” vent the air velocity (and therefore the flow rate) will drop even faster than the VADA’s.

3 Conclusion

The VADA Vent and the other two vents all work by equalizing the pressures below and above the roof membrane. However, the VADA Vent removes air at a rate approximately 2 times faster than the “mushroom” vent and 23 times faster than the “domes” vent. The other two vents are less useful as pressure equalizers; the low pressure generated by the “mushroom” vent and the tiny cross sectional area of the tubes on the “domes” vent handicap these two systems, as compared to the VADA Vent.

4 Further Investigation to Consider

As mentioned above, these are rough estimates based on simplified models. For more accurate and enlightening results, we could employ Computational Fluid Dynamics (CFD) computer modelling to simulate and compare the fluid flow in these vents, under variable conditions. This would better take into account any internal geometries that would reduce the flow efficiency. Alternatively, further physical tests on the actual vents, including measurements of flow rates and differential pressures (instead of just the static pressure) would provide further understanding of the relative merits of these devices.

5 Documents Relied Upon

- Images of VADA vents installed on roofs
- Results from pressure test performed by independent engineering company, including pressure results, physical measurements, and photographs for each vent.