ASD PIPING AND FITTINGS AIRFLOW PRESSURE DROP

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Abstract

An Active Soil Depressurization (ASD) radon mitigation system uses a fan to generate a negative pressure field under a concrete slab. The fan generating the negative pressure must overcome the resistance to airflow in the sub-slab and also the airflow resistance of the system piping. In this study, the pressure drop of typical ASD system piping was measured at varying airflow rates through 2-, 3-, 4-, and 6-inch piping and converted into a single pressure-drop calculation formula. The additional pressure drop induced by typical pipe fittings was measured at varying airflows by recording the difference between 20 feet of straight pipe and 20 feet of piping that included a fitting or fittings. The difference was then converted into the equivalent feet of straight pipe for each fitting type, as well as the pipe inlet opening.

1.0 Introduction

1.1 Reasons for Measuring Pressure Drop in Piping

Active Soil Depressurization (ASD) is recognized as the primary method of reducing radon or chemical vapors in the soil from entering a building. The 2023 version of the ANSI/AARST *Soil Gas Mitigation Standards for existing Multifamily, School, Commercial and Mixed-Use Buildings* (SGM-MFLB-2023) specifies that pressure field extension testing (PFE) shall be done before final design and system installation. The PFE defines the sub-slab resistance and how much airflow is required to depressurize the sub-slab. The final system performance with the chosen fan must also include the piping airflow resistance. In commercial buildings, the piping can be extensive, and the airflow is significantly higher than typical residential ASD systems. Commercial ASD systems that require high flow through the piping can have more pressure drop induced by the piping than by the sub-slab airflow resistance. (Brodhead, B 2024)

Piping airflow is induced by static pressure generated by a fan. The square of the CFM change equals the necessary static pressure change to achieve the new airflow. In other words, if the airflow is doubled, the static pressure needed to double the airflow must be increased by a factor of four. Calculating the piping airflow resistance is necessary to be able to include the optimal piping size and system layout, and to predict the final system performance. This paper includes measured pressure drop in piping and pipe fittings for four commonly used pipe sizes. The measured fitting pressure drop was converted to equivalent feet (EF) of piping resistance.

2.0 Methodology

2.1 Calibrating Flow Grid

Airflow measurements for all the testing done in this study were measured using circular inline flow grids and Energy Conservatory DG700 micro-manometers. The three flow grids used measured 4 inches, 5 inches, and 6 inches. In a previously published paper, the author described obtaining the flow grid calibration factor (CF) by comparing the flow grid to transverse pitot measurements as specified by ASTM and to an Alnor Lo-Flow hood (Brodhead, B. 1996). In June of 2019, SystemAir, at its facility in Kansas, tested WPB's 4-inch flow grid using their airflow measuring equipment. See Figure (1). The objective of this testing was to confirm that the airflow measurements were accurate within 5%. The result of this testing was that the WPB flow grid's original calibration factor of 59 needed to be adjusted 4.2% lower to 56.5 to match the flow rate measured by SystemAir. *See Figure (2) comparison of the 4-inch flow grid using a calibration factor of 56.5 with SystemAir data.* All airflow measurements are made using the current air density based on temperature, relative humidity, and barometric pressure. The formula for each of the flow grids is the following.

$$CFM = CF \times \sqrt{(\text{velocity pressure} / \text{air density})}$$

A second comparison test was run in 2024 using a new TSI Alnor 6200D LoFlo Balometer. TSI certifies that their instruments have been calibrated using standards whose accuracies are traceable to the National Institute of Standards and Technology within the limitations of NIST calibration services. The balometer used in this study was calibrated at the factory on 7/12/2023 to a tolerance of +/- 3% plus 5.0 CFM. *See Table (1)* that lists the performance of the balometer used in this comparison test versus the factory airflow measurements. The factory comparison data in supply mode was reported as less than 1% off. The comparison for the return mode was within 2% except around 100 cfm, which was about 5% high. WPB comparison testing also showed the balometer about 7% higher in this same CFM range compared to the WPB flow grid.

Figure (1): SystemAir Testing

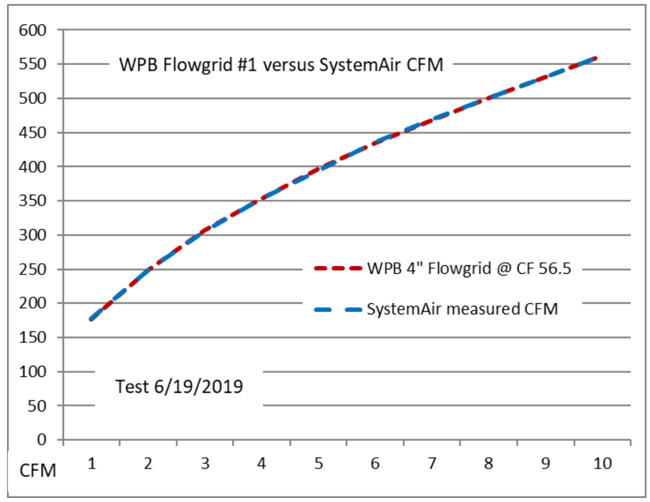


Figure (2): SystemAir vs WPB Flow Grid

Figure (3): Smooth transition from Balometer to 4” PVC

The transition set-up used to compare the balometer with the 4” flow grid is shown in Figure (3). A 10” round to 4” round transition pipe is attached to the 22-square-inch cardboard box that has all the seams taped. A ten-foot section of 4” pipe was installed from the 10” to 4” transition to an airflow straightener. Four feet of piping was routed from the air straightener to the WPB 4” flow grid. Eleven feet of 4” piping was routed from the flow grid to an RN4EC-4 fan that was set up in suction and then in pressure mode. The comparison between the WPB 4-inch flow grid and the balometer is shown in Figure (4). The comparison between the readings obtained from the balometer and the 4” flow grid using a calibration factor of 57 is displayed in Figure (5) and (6).

Figure (4): Alnor Balometer to Flow Grid Comparison

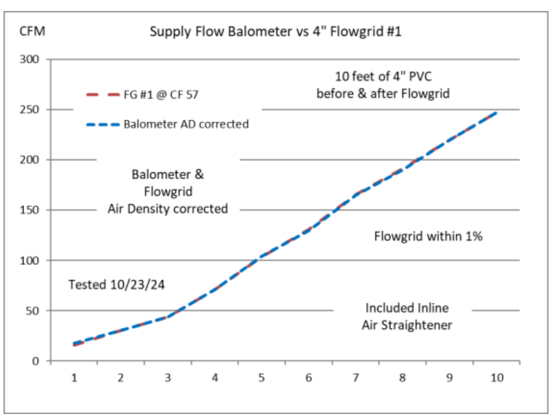


Figure (5): Supply Mode (Outflowing) balometer compared to WPB 4” flow grid

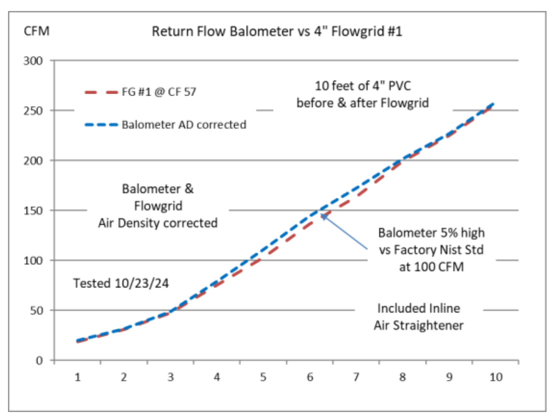
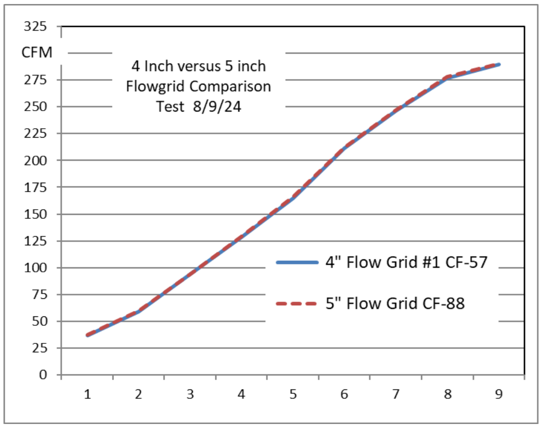


Figure (6): Return Mode (Inflowing) balometer compared to WPB 4” flow grid

2.2 Comparison to other Flow Grids

The 4-inch flow grid #1 was directly compared to the WPB 5-inch and 6-inch flow grids to obtain correct calibration factors for these two flow grids. See Figure (7).



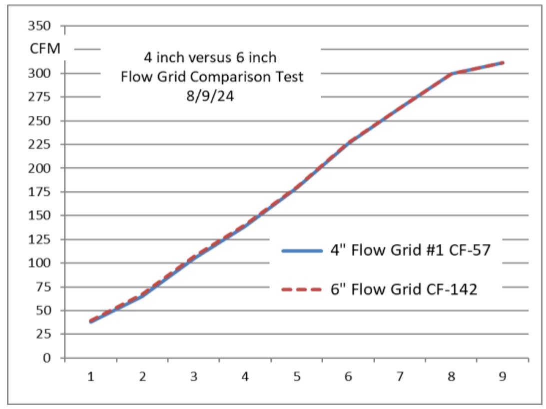


Figure (7): 4-inch flow grid compared to 5" flow grid and 6" flow grid

Supply Data		Return Data	
Factory Standard	Measured Output	Factory Standard	Measured Output
15	16	15	15
50	50	49	50
101	102	101	106
224	224	224	226
299	299	299	302

Table (1): Alnor Certificate of Calibration

MM 31003	MM60974
0.0103"	0.0103"
0.0318"	0.0318"
0.0820"	0.0820"
0.1423"	0.1425"
0.245"	0.245"
0.368"	0.368"
0.494"	0.494"
0.618"	0.619"
0.681"	0.682"

Table (2): Comparison of Micro-monometers

Two Energy Conservatory DG700 digital micro-manometers were used for all the velocity pressure readings to obtain the airflow rates and for the static pressure readings. The two micro-monometers produced nearly identical measurements to one another. The results are displayed in Table (2).

2.3 Comparison to HVI Fan Manufacturer Data

Home Ventilating Institute (HVI) is a well-recognized label attached to home ventilating equipment that provides uniform, certified testing of fan performance. Radon fan manufacturers will often have independent testing done on their fans by HVI. A comparison of the WPB fan's measured performance versus the manufacturer's listed HVI-certified performance was made to compare the results. See Figure (8).

In general, the WPB fan performance measurements were significantly higher airflow than the HVI certified fan performance listings. The discrepancy could not be explained, but it was suggested that turbulent airflow in the fan testing setup used by WPB was the cause. WPB includes about 6 feet of 4" piping before the inlet to the flow grid for fan testing. The first testing with the Alnor Balometer in 2024 used a similar setup to that used for the fan testing. The results of this test confirmed that a CF of 57 was correct for the 4" flow grid.

The data provided by WPB on their website (www.wpb-radon.com) has been presented uniformly for all fans, so direct comparisons can be made between different fan models. The piping and fitting pressure drop defined in this study is provided primarily to design commercial and residential ASD systems that are used in conjunction with PFE measurements that also measure airflow based on the same reference source, so that all the data is compatible.

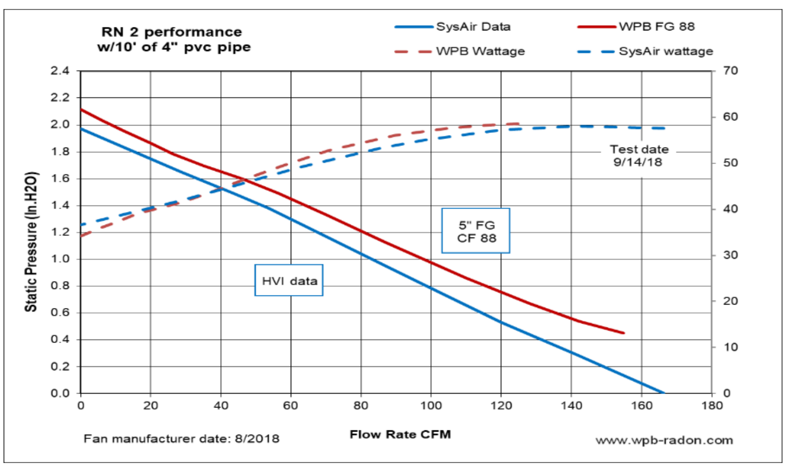


Figure (8): WPB RN2 Performance measurements versus HVI data

2.4 Straight Piping Experimental Setup

All of the piping, fittings, and measurements used in this study were made using US Imperial-sized components. In order to determine the pressure drop caused by airflow through straight piping, the author in 2007 set up approximately 100 feet of piping for each of the pipe sizes, 2-inch, 3-inch, 4-inch, and 6-inch. Dwyer six-inch pitot tubes were used to measure the static pressure by inserting them halfway into each pipe with the total pressure port sealed. The tube was held securely in place using a triangle square taped to the pipe. See Figure (9) and Figure (10). The static pressure port of the pitot tube was spaced 40 feet and 60 feet apart. See Figure (11). Pressure measurements were made using the averaging function of a DG700 and waiting until the micro-manometer readings stabilized. The airflow was measured using a flow grid that had been previously calibrated as reported in previous papers (Brodhead, B. 1996). The flow rates were later adjusted to the new calibration setting obtained from SystemAir testing in 2019 and confirmed in 2024 with the Alnor balometer.

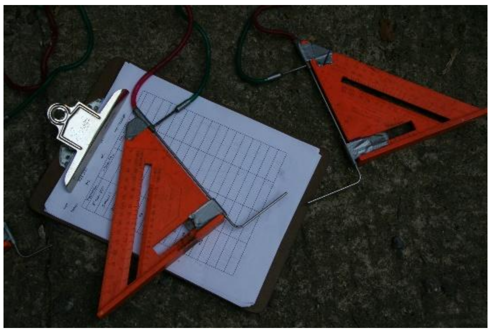


Figure (9): Dwyer Pitot tube secured in the piping

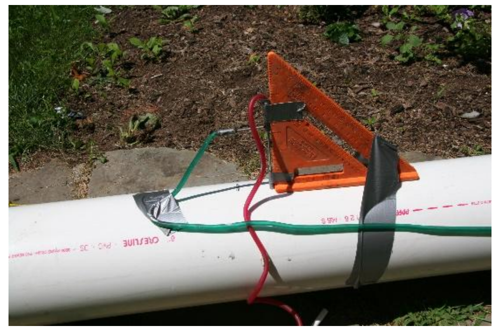


Figure (10): Dwyer Pitot tube using only static port

Figure (11): 100 feet of piping with pitot tubes and fan

The pressure drop for each distance of piping was converted to the pressure drop of 100 feet of that pipe size. The comparison of the results of the airflow measurements made in 1996 versus 2007 is displayed in Figure (17) through Figure (18). Figure (21) and Figure (22) provide the combined results of different pipe sizes using the 60-foot-long pressure drop results.

In the 1996 paper (Brodhead 1996), the straight pipe pressure drops at different air flows were compared to the results of the Darcy formula given in the ASHRAE Fundamentals Handbook (ref 3) to determine how well they compared. In general, the Darcy equation given in ASHRAE Fundamentals overpredicted the pressure drop of straight piping pressure drop by 9% to 18% for 3-to-6-inch piping. The variation in measured values versus calculated values for fittings varied significantly and in different directions. All of the piping used in the 1996 and this study was sewer and drain (ASTM D2729), which has the same ID as Schedule 40 piping (ASTM D1785) but has a thinner pipe wall thickness. All of the fittings in the 1996 study were sewer and drain fittings. All of the fittings presented in this study are schedule 40, with PVC adapters to transition between the sewer and drain piping and the schedule 40 fittings.

2.5 Pipe Fitting Experimental Setup

For the fitting pressure drop tests, a straight section of piping had a Dwyer pitot static pressure probe inserted about five to ten feet from the piping inlet. The inlet had an expanding flared fitting attached to the inlet to reduce turbulence. A second pitot tube was inserted exactly 20 feet upstream (closer to the suction fan) in a straight section of piping to record the pressure drop in 20 feet of straight pipe. See Figure (12). A PVC fitting was installed exactly ten feet upstream from the second pitot tube. A third pitot tube was installed exactly ten feet from the PVC fitting further upstream. A triangle, square, and tape were used to secure each of the pitot tubes and allowed easy confirmation that the static port was parallel to the airstream and centered in the pipe. See Figure (10). The total pressure port of each pitot tube was sealed. Each pitot tube was set so that it minimized disturbance of the air stream. All of the piping and fitting connections were wrapped with tape to ensure air tightness. See Figure (30). The pressure difference between the 20 feet of straight pipe was measured and recorded at the same time the 20 feet of piping and fitting or fittings were measured and recorded. The fan airflow volume was adjusted from the highest to the lowest flow rate using the voltage adjustment knob of the Fantech RN4-EC diagnostic fan. The Energy Conservatory DG700 micro-monometers were reset to average mode for each air speed setting, and the results were recorded after all the measurements stabilized. Nine different airflows were measured and recorded for each fitting type that was tested.

The pipe fittings that were used were obtained from a local professional plumbing store. The fittings were defined as a sweep, a long sweep, an angled turn, or a hard turn, depending upon the radius of the turn. Hard turn 90-degree fittings, in this case, refer to a 90-degree fitting that makes a right-angle turn on the inside edge. Angled turns refer to 45-degree fittings that have a sharp angle turn on the inside edge. Sweep fittings are typical PVC fittings that have a smooth radius turn on the inside edge. Long sweeps are fittings that have an extended inside radius that elongates the fitting for a more gradual turn. These long sweep fittings were not tested.

Pressure drop in the ASD system piping was calculated based on the footage of piping used and the airflow velocity through the piping. The contribution of pressure drop from pipe fittings is defined in this paper as the amount of equivalent feet of straight piping each fitting or combination of fittings or initial open inlet of piping adds equivalent straight piping footage at the same airflow. In this study, the term "equivalent feet" or "equivalent piping footage" will be referred to as "EF. The equivalent feet of piping for each fitting or fittings are displayed in graphs showing the variation in EF as the airflow changes. See Figure (23) through Figure (28).

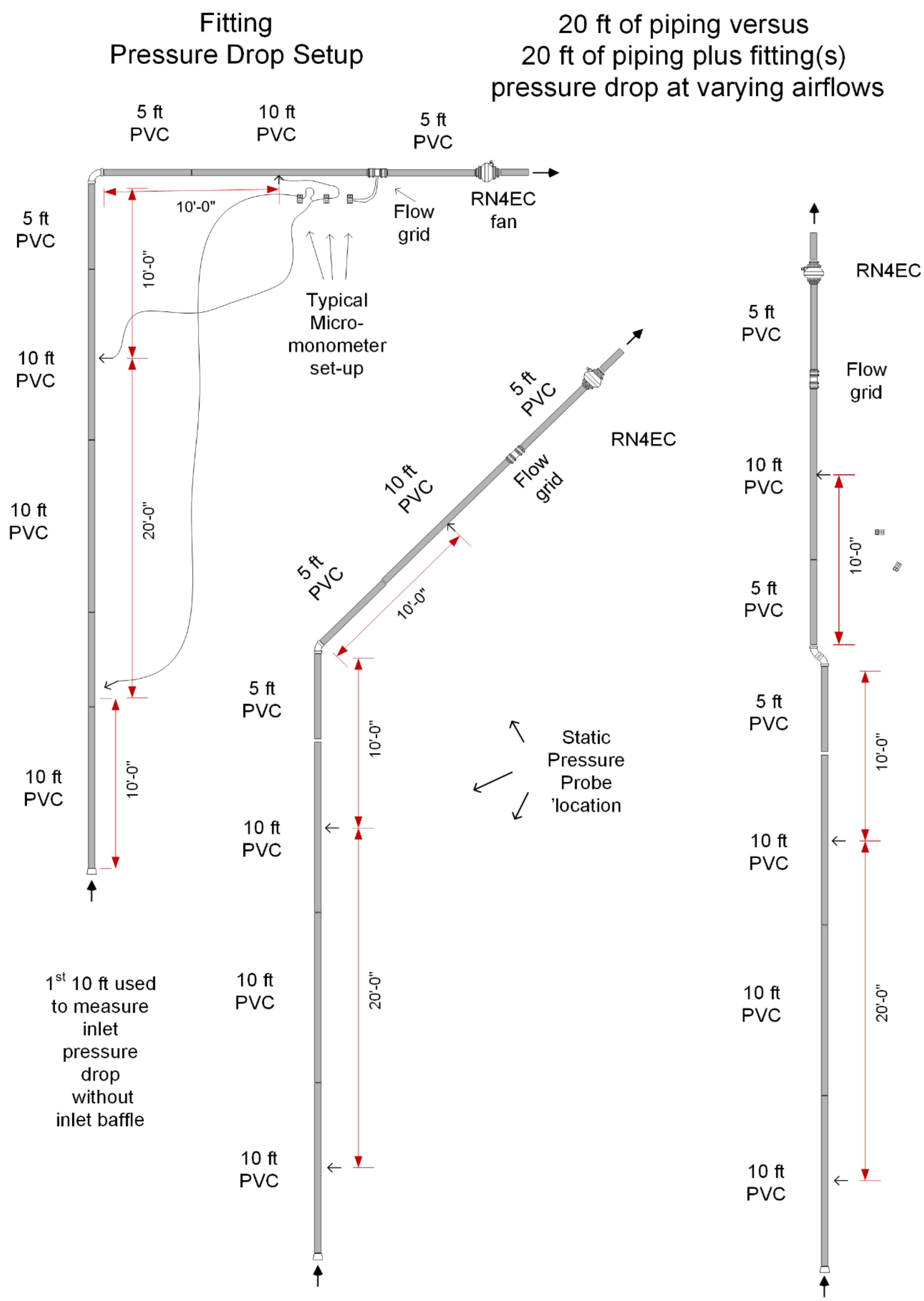


Figure (12): PVC fitting EF measurement test layout

Figure (13): 6” Sweep 90-degree elbow

Figure (14): Flared intake

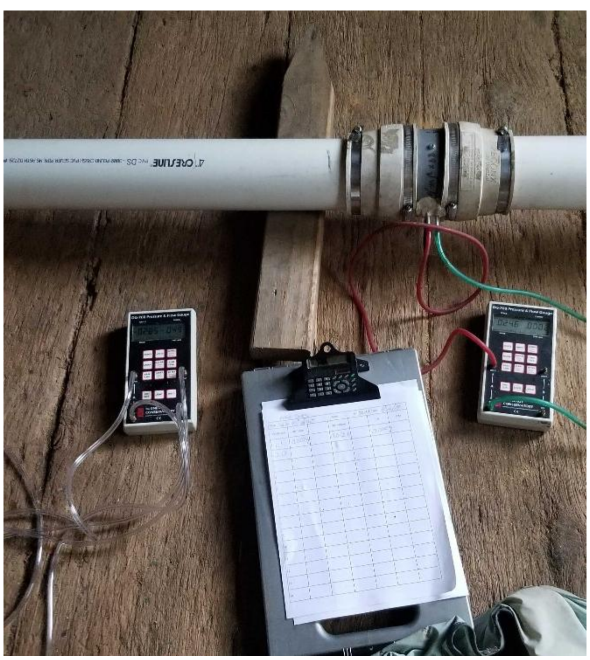


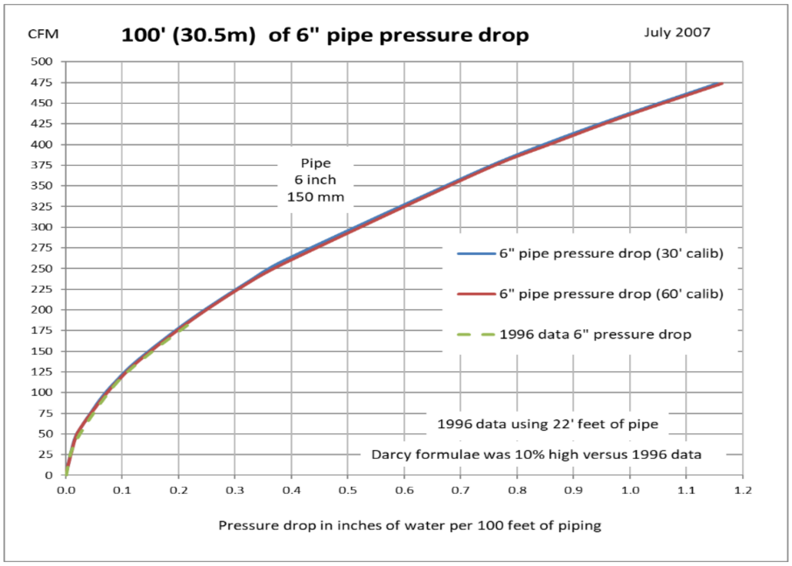
Figure (15): Five-inch flow grid used to make 4” PVC airflow measurements

Figure (16): Adjustable RN4EC fan

3.0 Results & Discussions

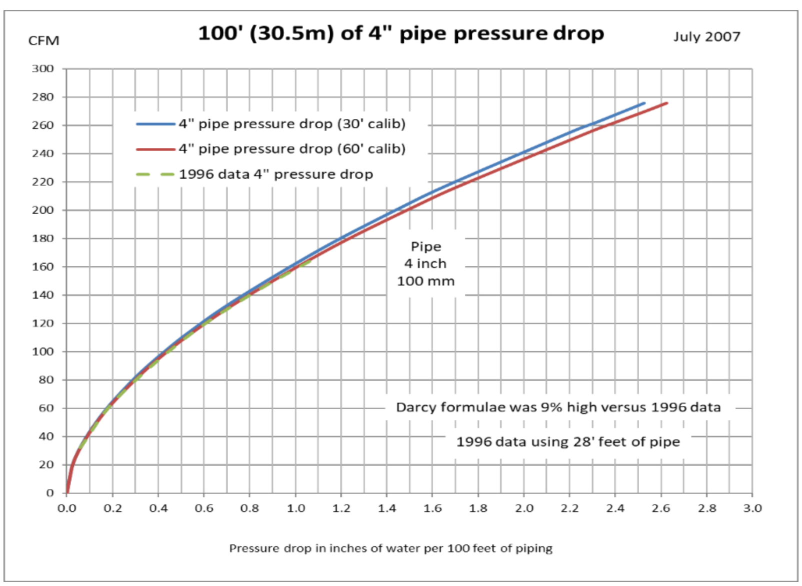
3.1 Airflow versus Pressure Drop Charts

Pressure drops for the 2”, 3”, 4”, and 6” pipe sizes were measured across 30 feet and 60 feet of piping at increasing airflows. The results are illustrated in Figure (17) to Figure (20).



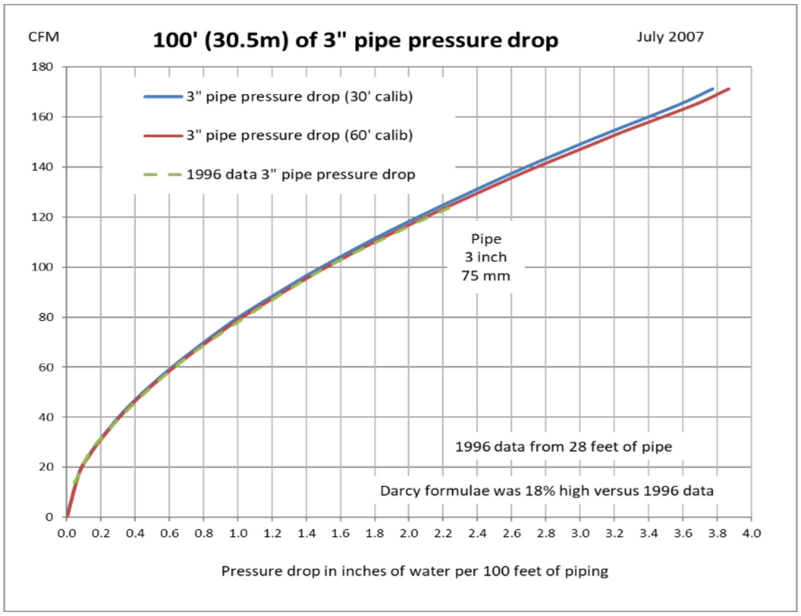
In Figure (17) the measurements made in 1996 duplicated the measurements made in 2007 using the flow grid 57 calibration factor.

Figure (17): Pressure drop of six -inch (150mm) piping per 100 feet



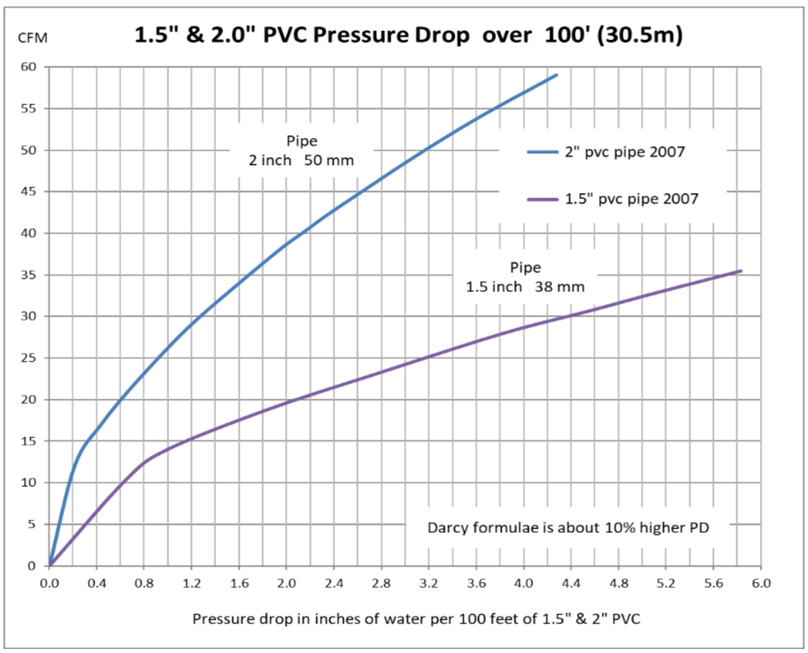
There was a difference of about 2% at the highest airflow between the 30-foot measurements and the 60-foot measurements with 4-inch piping. The 1996 measurements more closely match the 60-foot measurements more perfectly. The 60-foot measurement was used for the pressure drop calculations of airflow through 4-inch piping.

Figure (18): Pressure drop of four -inch piping per 100 feet



In Figure (19), the 60-foot measurements more closely match the 1996 data. The 30-foot measurement was about 2% higher at the highest airflow tested compared to the 60-foot measurements. The 60-foot measurement was used for calculating the pressure drop for 3-inch piping.

Figure (19): Pressure drop of three -inch piping per 100-feet



In Figure (20), the 60-foot pressure drop test results are used to define the 1.5-inch and 2-inch 100-foot piping pressure drop.

Figure (20): Pressure drop of six-inch (150mm) piping per 100-feet

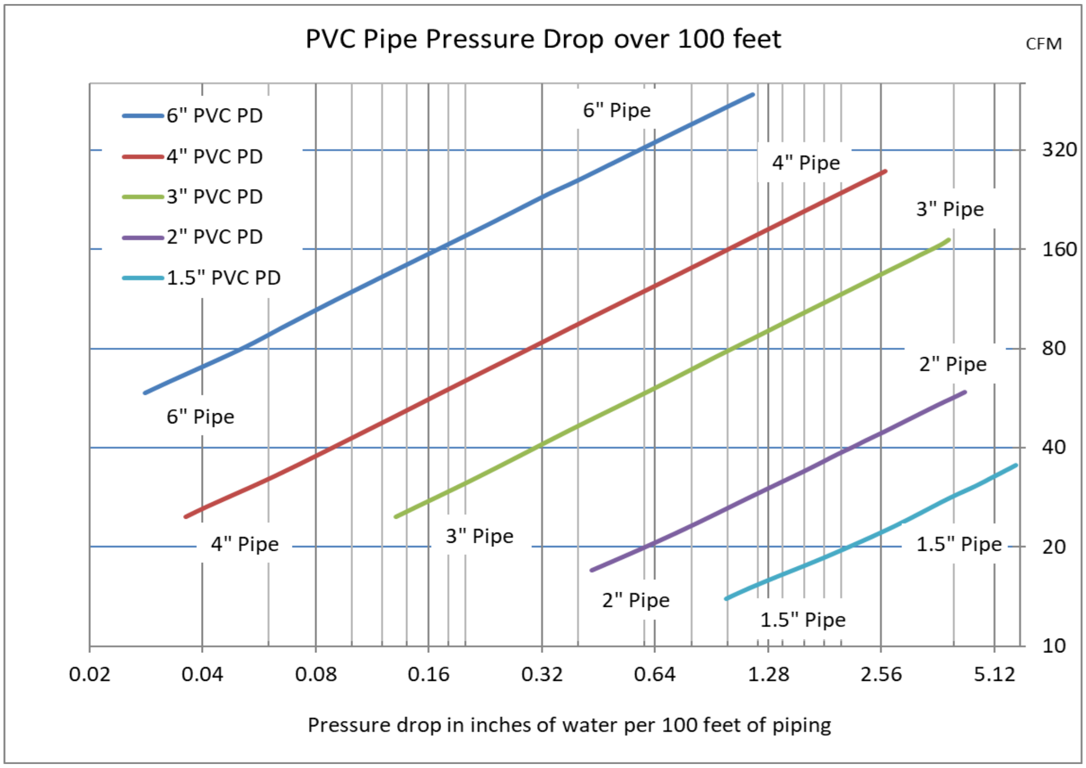


Figure (21): Airflow versus pressure drop for 100 feet of different pipe sizes.

3.2 Simplified Pressure Drop Formula

In order to convert the data collected into a usable formula, Kevin Stewart (Stewart, K. 2023) provided the needed assistance to determine a simplified single formula. Formula (1) provides the pressure drop value for four common pipe sizes at any typical airflow. The formula to determine pressure drop requires three inputs: airflow in CFM, piping inside diameter (ID) in inches, and total equivalent feet of piping and fittings. See Reference 5 and Formula (1). The formula can be easily entered into a spreadsheet and used to determine piping pressure drop for a single suction ASD system. This single formula allows the use of any common mitigation pipe size and any amount of total equivalent feet of piping.

Pressure Drop = ((0.202 * CFM * Pipe ID inch ^-2.5) ^1.7) * (Total EF/100)

or

Pressure Drop = (0.063 * CFM ^1.755 * Pipe ID inch ^-4.42) * (Total EF/100)

Formula (1): Two separate spreadsheet formulas that calculate pressure drop by inputting the CFM airflow and pipe size in inches. Either can be used.

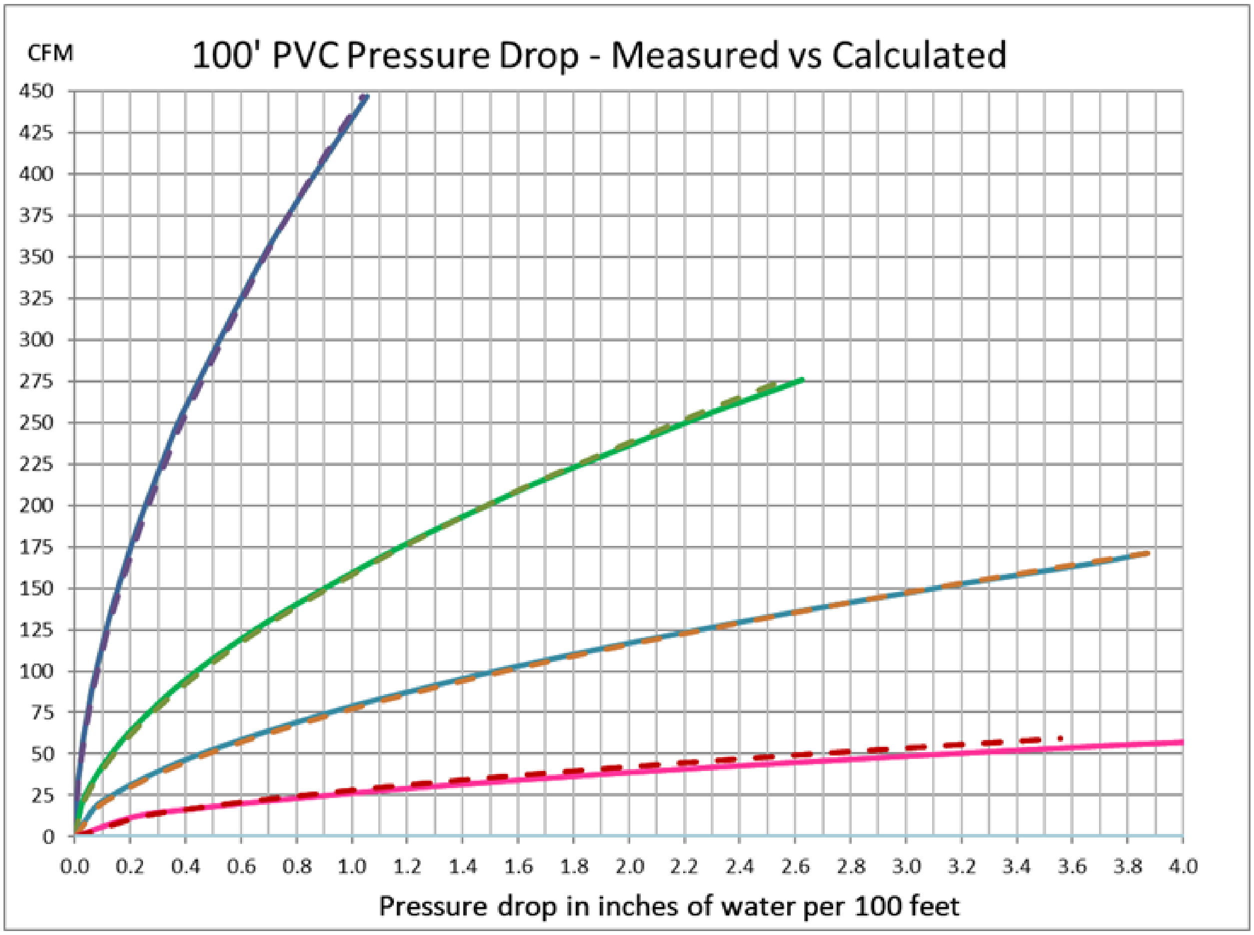


Figure (22): Piping pressure drop Measured (solid line) vs Calculated (dash lines)

In Figure (22) the measured pressure drop per 100-feet of piping is compared to the results using Formula (1) formulas. Both formulas closely match the measured values.

<u>3.3 Comparing Total System Airflow Resistance to Fan Performance</u>

The total EF of piping needs to include the proposed straight piping and additional equivalent feet from fittings and the pipe airflow opening. The PFE measurements made in the field, which measure the sub-slab airflow resistance to airflow, are then added to the piping airflow resistance. The total airflow resistance results are then plotted on a log-log xy (scatter) graph, which produces a straight line. Fan curves are then overlaid on the graph to depict what airflow individual fans can produce. The total resistance line can be extrapolated to higher airflows to match a fan curve that produces a higher airflow than what was generated by the PFE testing.

3.4 Pipe Fitting Pressure Drop Converted to EF of Piping at Varying Airflows

The pressure drops induced by pipe fittings need to be added to the piping pressure drop to determine the total pressure for a specified airflow. Rather than determining a pressure drop for each fitting, it is more practical to determine the fitting resistance as equivalent feet (EF) of piping for the same pipe size and airflow using the following formula.

$$EF = \text{Fitting } \Delta p \; / \; \text{1ft pipe } \Delta p$$

The EF of piping for individual pipe fittings was measured using the setup detailed in Section 2.5. The results of increasing airflow are graphed in Figure (23) through Figure (36). In each fitting test, as the airflow increases, the EF also increases. Table (3) summarizes a recommended single EF for each fitting to provide a simplified method of adding additional piping length to approximate the additional fitting pressure drop.

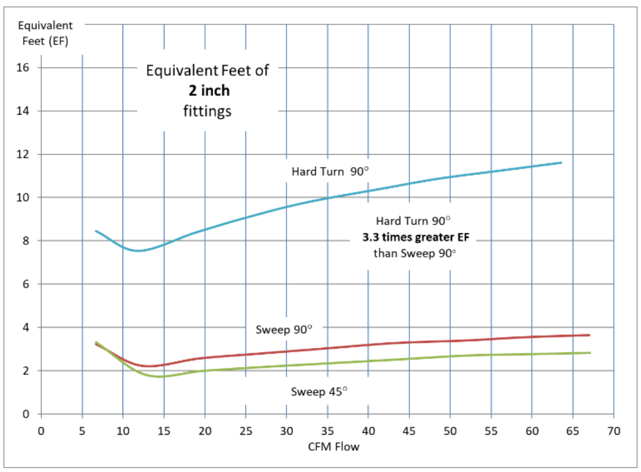


Figure (23): Two-inch (38mm) pipe fittings

In general, the smaller the pipe diameter, the less EF of piping each fitting adds to the total pressure drop of the piping system. In Figure (23), two-inch (38mm) sweep 45-degree and 90-degree fittings have a 2 to 3 or 3.5 EF for every elbow installed. A two-inch 90-degree hard turn fitting was tested and had an EF increase by a factor of three to an 8 to 11 EF. The two-inch fittings had a reverse increase in EF at the lowest airflow. This was not seen in other pipe sizes.

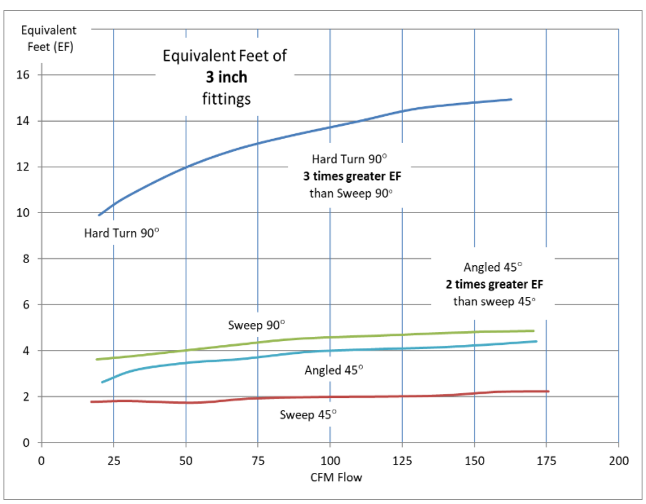


Figure (24): 3-inch (75mm) pipe fittings

The EF of 3-inch (75mm) fittings was about two feet for a standard sweep 45-degree fitting and about four to five feet for a sweep 90-degree fitting. If the 45-degree fitting has an angular turn, the EF increases by about a 2.5 times factor to about five feet. A 90-degree hard turn fitting increases the EF by almost a factor of three compared to a sweep 90-degree fitting. The two angled 45-degree offset fittings refer to the two fittings installed offset to each other, with a short piece of piping installed between them. See Figure (12) which has a drawing of the offset testing layout.

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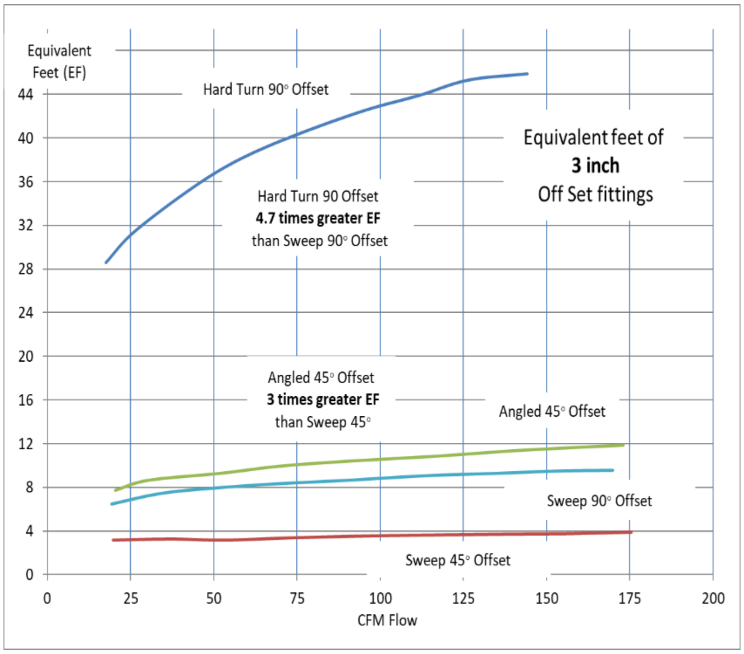

Figure (25): 3-inch (100m) pipe offset fittings

When two similar fittings are used to create an offset around an obstacle, the two fittings can be installed together using one male-to-female fitting that is referred to as a street, and one double bell fitting or two double female fittings can be used with a short piece of pipe. This arrangement of two similar fittings offset a short distance is typically additive in EF if the fittings are sweep types. If 45-degree fittings are angular or even hard turn, then the EF of two fittings installed together is closer to three times the EF of a sweep 45-degree offset fitting. If the offset uses two hard turn 90-degree fittings, the EF increases by a factor of 4.5 times a sweep 90-degree offset. In general, if an offset uses two sweep fittings, the individual EF of the fitting applies.

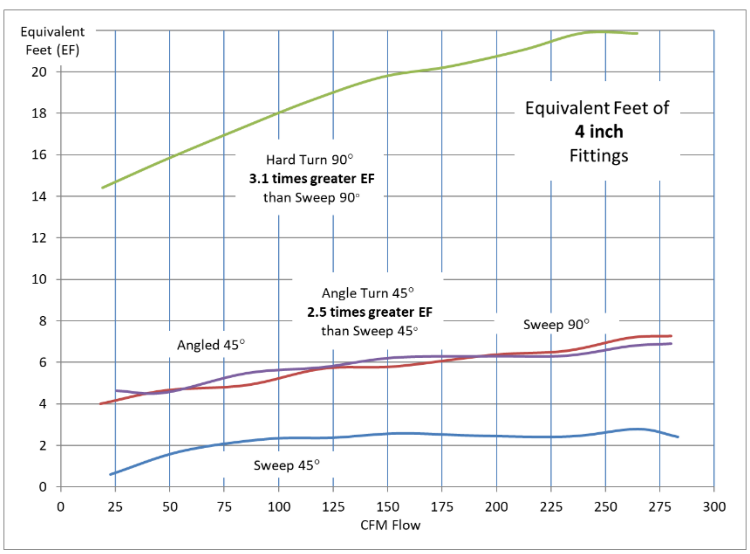

Figure (26): 4-inch pipe fittings

4-inch (100mm) fittings EF were about two and a half feet (0.75m) for a single sweep 45-degree fitting and about six feet for a single sweep 90-degree fitting. If a single 45-degree fitting has an angular turn, the equivalent feet is about 5 to 7, or about 2.5 times greater than a sweep 3-inch 45-degree fitting. A single 90-degree hard turn fitting increases the EF by a factor of 3.3 compared to a single sweep 90-degree.

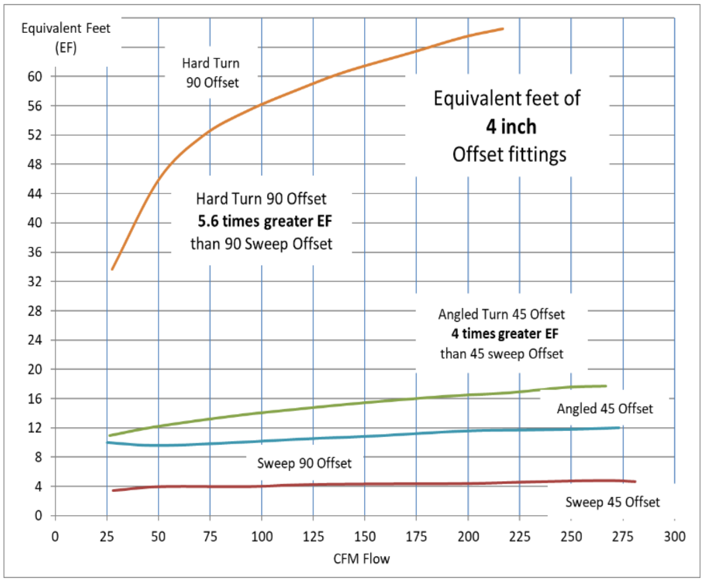

Figure (27): Hard Turn offsets had 5.6 times more EF than Sweep offsets.

Figure (27) shows fitting pressure drops when two 4-inch fittings are offset to each other. The two hard turn fittings are listed as Sch20, or their other reference name of Sewer and Drain (S&D). Sch20 is a thinner-walled pipe than schedule 40, but has the same ID size. Sch20 is often used for below-grade drainage pipe. In comparing the EF of fittings made for S&D piping, the pressure drop per fitting compared to schedule 40 fittings is typically greater. The hard turn Sch20 90-degree offset had 5.6 times the pressure drop of the offset sweep 90-degree fitting. The angled turn 45-degree offset was 4 times greater EF than the offset sweep 4-inch fittings.

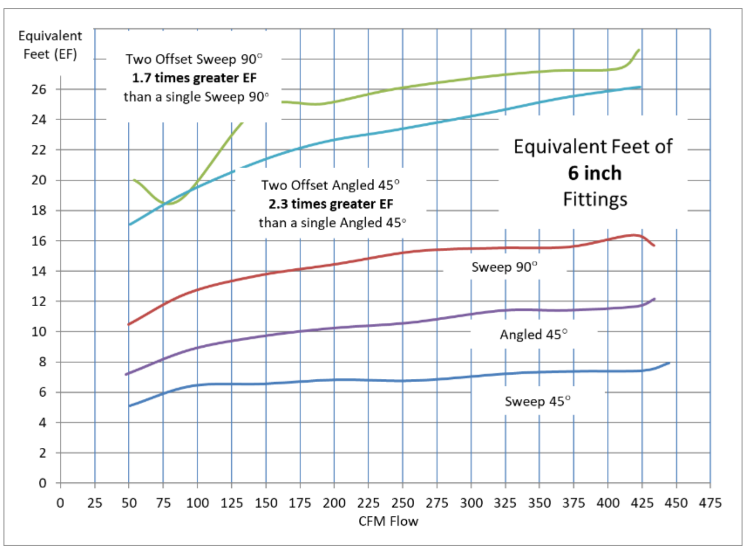

Figure (28): Six-inch pipe fittings

Figure (29): Six-inch 90 degree sweep offset fittings

Interestingly, the EF of offset 6-inch (150mm) sweep 90-degree fittings had less than double that of a single 90-degree sweep fitting. The offset angular 45-degree fittings were 2.2 times greater than a single angular turn 45-degree fitting.

Figure (30): Six inch angled 45 degree offset pipe fittings

3.5 Fitting Pressure Drop Calculations

In order to determine the approximate equivalent feet (EF) of piping for different fittings that would commonly be used by ASD installers, a simplified formula was developed for each fitting that most closely matches the measured EF of each fitting as airflow changed. The formula is given in Formula (2). Tables (5), (6), and (7) include all the C (constant) and V (Variable) factors for each fitting or fitting type.

$$EF = C + (V * CFM)$$

Where:
C is a constant for each fitting
V is a variable for each fitting
CFM is the airflow through the fitting.

Formula (2): Fitting pressure drop equivalent feet of piping

In Figure (31) to Figure (36) the measured EF of each fitting at varying airflows was compared to the results using Formula (2). The dashed lines represent an approximate linear calculation of the pressure drop as CFM increases. The fitting constant and variable are included in Tables (5), (6), and (7).

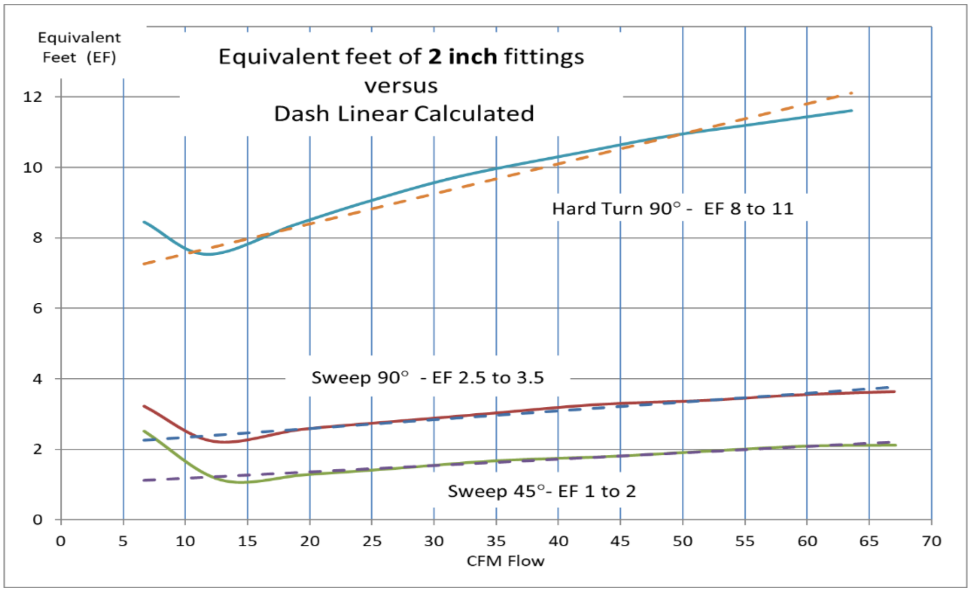

Figure (31): Comparison Calculated versus measured 2-inch fitting EF

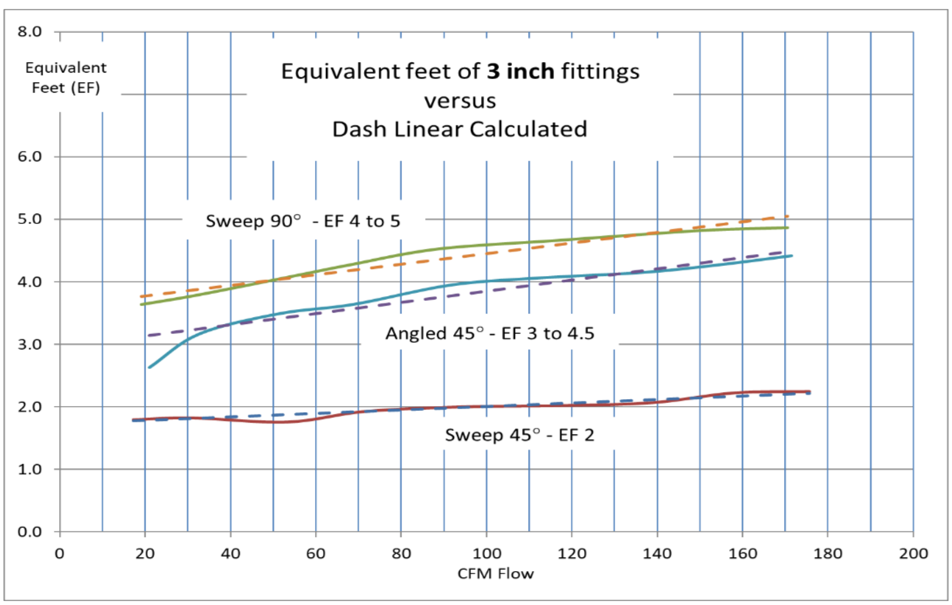

Figure (32): Comparison Calculated versus measured 3-inch fitting EF

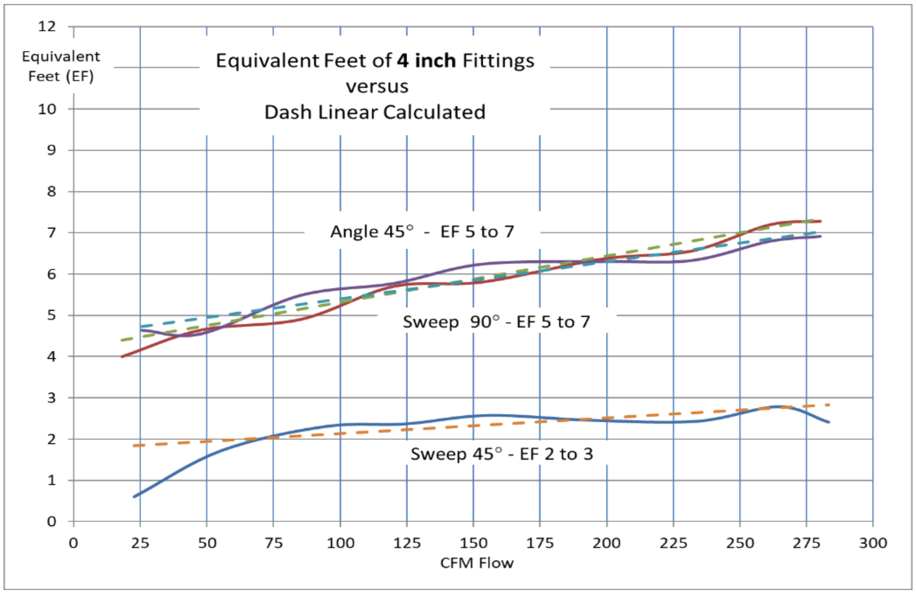

Figure (33): Comparison Calculated versus measured 4-inch fitting EF

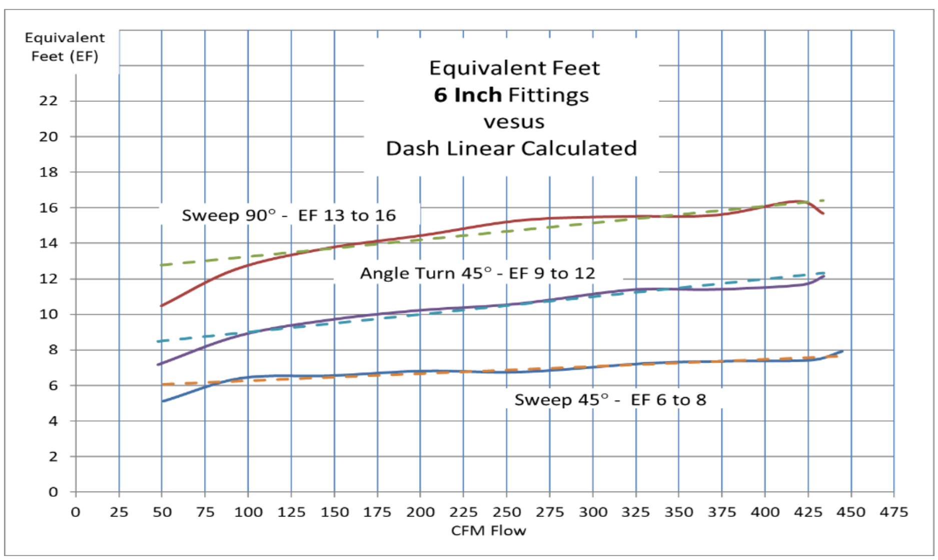

Figure (34): Comparison Calculated versus measured 6-inch fitting EF

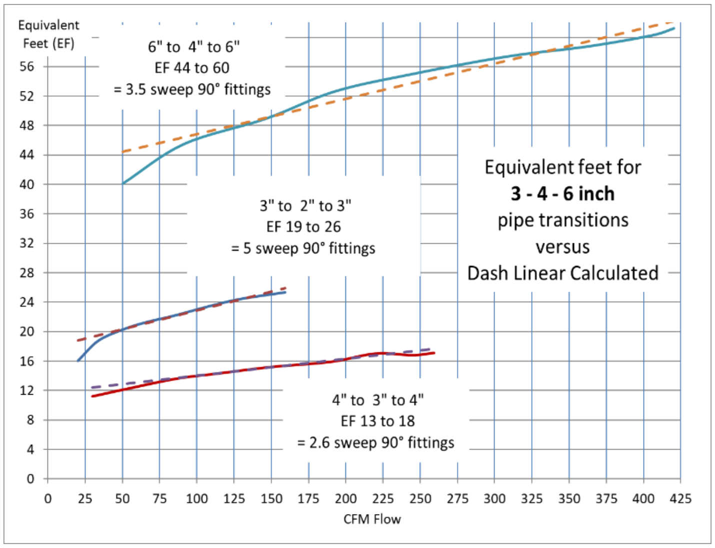

Figure (35): Reducing pipe size & calculated value

When running pipe in a commercial ASD installation, there are often obstacles that require the piping size to be reduced and then transitioned back to the original size, or just reduced in pipe size. In Figure (35), the pressure drop in EF was measured for transitions of 3-inch to 2-inch back to 3-inch piping, for 4-inch to 3-inch and back to 4-inch piping, and also for 6-inch to 4-inch back to 6-inch. The transition EF when piping is downsized to a small pipe size in piping networks is assumed to be similar EF as the measured transition EF in this study.

The 4-inch to 3-inch to 4-inch piping transition was equal to about 2.6 sweep 90-degree 4-inch fittings. The 3-inch to 2-inch to 3-inch piping transition was a larger pressure drop equal to about 5 sweep 90-degree 3-inch fittings. The 6-inch to 4-inch to 6-inch transition equaled about 3.5 sweep 90-degree 6-inch fittings. The lower EF of 4-inch to 3-inch transitions was unusual and may require retesting to verify.

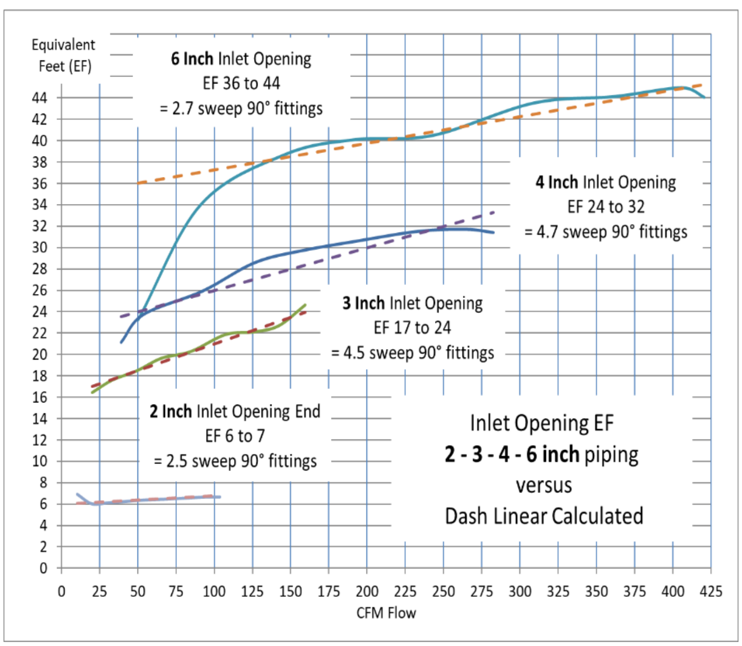

Figure (36): Piping EF at pipe inlet

As air enters the system piping in a typical suction pit, there is no smooth transition of airflow. Some of the incoming air must make a hard turn at the edges to enter the pipe. The initial pressure drop was measured for both non-tapered openings and tapered from 3-inch and 4-inch piping runs to an 8-inch round tapered opening. In general, the tapered opening reduced the pressure drop EF by about 35%.

Without a tapered inlet, the opening to the 3-inch pipe had the EF of 4.5 sweep 90-degree 3-inch fittings. The open 4-inch pipe had the EF of 4.5 sweep 90-degree 4-inch fittings. The 6-inch pipe and 2-inch pipe inlet EF had the least pressure drop, with EF of about 2.6 for sweep 90-degree fittings of the same size pipe.

Pipe Size	CFM airflow	Sweep turn 45° EF	Angled Turn 45° EF	Sweep turn 90° EF	Hard turn 90° EF	Open Pipe inlet EF	Transition to smaller pipe
2-inch	10 - 60	2’ to 3’		2.5’ to 3.5’	8’ to 11’	6’ to 7’	
3-inch	25 - 175	2’ to 2’	3’ to 4.5’	4’ to 5’	11’ to 15’	17’ to 25’	16’ to 25’
4-inch	25 - 275	2’ to 2.5	3’ to 7’	3’ to 7’	15’ to 22’	22’ to 32’	11’ to 17’
6-inch	50 - 450	6’ to 8‘	8’ to 12’	12’ to 16’		36’ to 44’	44’ to 60’

Table (3): Fitting EF as airflow is varied

In Table (3) the range of EF recorded for each fitting is displayed. In general, it is recommended to use the higher EF values for ASD system design because a significant portion of the total system airflow resistance happens at higher airflows. At lower air flow rates, the sub-slab airflow resistance is generally the predominant portion of the total system airflow resistance.

Pipe Size	Sweep turn 45° EF	Angled Turn 45° EF	Sweep turn 90° EF	Hard turn 90° EF	Open Pipe inlet EF	Transition to smaller pipe
2-inch	3’		3.5’	11’	7’	
3-inch	2’	4.5’	5’	15’	25’	25’
4-inch	2.5’	7’	7’	22’	32’	17’
6-inch	8‘	12’	16’		44’	60’

Table (4): Recommended EF for each fitting or pipe inlet used

Fitting Type Factor	Sweep 45° EF	Angled 45° EF	Sweep 90° EF
2" - C	**1.0**		**2.1**
2" - V	0.018		0.025
3" - C	**1.725**	**2.95**	**4.2**
3" - V	0.0028	0.009	0.0085
4" - C	**1.75**	**4.5**	**4.2**
4" - V	0.0038	0.009	0.0112
6" - C	**5.86**	**8.0**	**12.3**
6" - V	0.004	0.01	0.0095

Table (5): Fitting EF = C + (V * CFM)

Fitting Type Factor	3" to 2" to 3" EF	4" to 3" to 4" EF	6" to 4" to 6" EF
C	**17.8**	**11.7**	**42**
V	0.051	0.023	0.048

Table (6): Transitions EF = C + (V * CFM)

Fitting Type Factor	2" Inlet Opening - EF	3" Inlet Opening - EF	4" Inlet Opening - EF	6" Inlet Opening - EF
C	**5.9**	**16**	**22**	**34.75**
V	0.013	0.05	0.04	0.025

Table (7): Inlet Opening EF = C + (V * CFM)

Table (5), (6), and (7) list the Constant (C) and the Variable (V) used for each fitting or Inlet Opening to determine the equivalent feet of pipe as the CFM flow through the fittings or transitions changes.

4.0 Conclusion

4.0 Piping Pressure Drop and Fitting EF Conclusions

In designing an Active Soil Depressurization (ASD) system that is commonly used to reduce soil gas movement into a building, the resistance of airflow movement from a single suction pit location is determined by performing a Pressure Field Extension (PFE) test. The additional pressure drop from the pipe and fittings used in the system must be included to calculate the total system airflow resistance. The results of both these resistances to airflow allow comparison to commonly available suction fans to determine the final system's expected airflow. As the system airflow increases, the resistance of the airflow through the piping increases by approximately the square of the airflow increase. In high-airflow systems that have low sub-slab airflow resistance, the piping can be a greater resistance to airflow than the sub-slab airflow resistance. Determining the airflow resistance of the required piping length and number of fittings becomes a crucial component of commercial ASD design. The calculation of piping resistance for different pipe sizes also allows choosing the optimal pipe size. This study measured the resistance of airflow through piping and pipe fittings for four common ASD pipe sizes. The study also measured pipe fitting resistance based on the sweep or angled, or hard turn of the fitting. All of the fitting measurements were converted into equivalent feet (EF) of piping for the same airflow. Table (4) provides the recommended fitting or opening EF per fitting used. The total fitting EF can then be added to the piping length to obtain the total EF of the system piping. Formula (1) in this study can then be used with the total EF for the specified pipe size to determine the pressure drop for any given CFM airflow. This method can be repeated for all common radon or vapor intrusion pipe sizes or any EF length. For multiple suction systems connected to a single suction fan, the airflow from each suction pit can be considered as a percentage of the total system airflow and piping pressure drop can be calculated at the given percentage of airflow for the individual legs of the system to approximate the pressure drop and final sub-slab suction that is applied for a given fan.

5.0 References

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6. Note: QuillBot free version was used for spelling, grammar, tense, and punctuation.