RADON FAN PERFORMANCE; A UNIFORM SET OF EMPIRICAL TESTS

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ABSTRACT

The production of radon control fans has been dominated by two companies, each of which manufactures several different fans for radon control applications. In the absence of standardized performance data regarding the pressure and flow characteristics of these fans under nominal radon control conditions, a simple series of tests was designed to measure those characteristics. The resulting data are presented here so that radon mitigators have a uniform data set from which to judge the performance characteristics of available fans.

INTRODUCTION

A survey of five radon supply catalogs indicates approximately three dozen fans marketed for general radon control applications with static pressure ranges from 1 - 5"WC and unobstructed flows of 0 - 250 cfm (1), as well as other fans for applications which require static pressures in excess of 5.0" WC, flows in excess of 250 CFM, or other special applications. To test the comparative performance of commonly used fans, fifteen models were selected with nominal pressures up to 5"WC and flows up to 250 CFM. The fans were tested for actual flow at prescribed pressures using a standardized test bench designed to simulate a simulated base-case radon control system application. Measurements of electric consumption were made at the same time as pressure and flow measurements, and all of the data is presented here in tabular form.

METHODOLOGY

To simulate a typical, simple radon control application, all measurements were conducted on a test bench consisting of a 4" diameter schedule 20 pvc inlet pipe, a flexible coupling mounted to the fan, and a flexible coupling mounting the fan to a 4" diameter schedule 20 pvc exhaust pipe. The inlet pipe was 88 inches long and the exhaust pipe was 32 inches long, resulting in an overall length of 120 inches from inlet to outlet, thus roughly approximating the simplest of systems which might be installed in a residential house. The test apparatus was horizontal and included no bends or elbows. A 3.75" flow grid was installed in the middle of the inlet side of the 4" piping (40 inches from inlet to flow grid and 40 inches from flow grid to fan) and a pitot tube was locaed approximately halfway between the flow grid and the inlet to the fan. The static pressure probe of the pitot tube was inserted into the center of the pipe to measure the static pressure below the fan.

Each fan was tested in sequence by installing it with the appropriate couplings and making a series of seven pressure and flow measurements using a series of restrictive caps to regulate input resistance. Each of the caps was made by drilling a series of 1 to 5 holes in a pvc end cap and placing it on the inlet side of the system to simulate soil resistance. The initial measurement in each series was made with no end cap and nominally unrestricted flow (except for pipe resistence), measurements two through six were made with one to five holes drilled in each end cap, and the final measurement was made with the inlet pipe capped (closed).

Pressure measurements were made using a digital micromanometer, and measurements of wattage were made simultaneously using a Wattprobe meter wired inline (and measuring in 10 watt increments.)

This test methodology was designed to objectively compare the performance of different fans using technically sound practices under a uniform set of conditions: nonetheless, several caveats are essential. First, only one fan was tested for each model. Second, each fan was tested only once. Third, the test data represents only one set of environmental conditions. Fourth, fans were mounted horizontally for these tests (in-line with the horizontal pipe layout). Thus, while these tests represent a consistent set of tests under a simulated "real-world" configuration, they represent only a single set of test data.

FAN PERFORMANCE DATA

Table 1 indicates the measured air flows at specified pressures ranging from unrestricted (0" WC) to fully restricted (capped) air flow.

Fan	Flow @	-------------------- Pressure (inches WC) --------------								Pressure
Model	0" WC	0.5	0.75	1.0	1.25	1.5	2.0	2.5	3.0"	@ 0 CFM
	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(" WC)
XP101	120	108	88	63	36	8				1.58
XP151	134	128	102	69	32	3				1.52
XP201	112	98	80	65	43	21				1.78
XR161	133	115	72	45	26	10				1.72
XR261	155	165	115	79	52	36	5			2.10
GP201	78	70	67	61	52	44	21			2.04
GP301	84	80	70	67	62	55	40			2.47
GP501	92	90	85	80	75	70	62	42	12	4.21
FR100	110	82	40							0.92
FR150	172	187	158	122	85	39				1.95
FR175	216	--	--	230	187	160	76	13		2.89
HP190	136	132	112	90	70	45	5			2.08
HP220	210	--	--	210	180	152	75	15		2.59
ECL452	134	120	107	76	31					1.26
RAM2	145	122	100	70	37	1				2.02

Table 1: Pressure and flow measurement data for radon fans

Tables 2 - 4 compare these test results with the published data with the performance data published in the catalogs (2), and Figures 1 - 3 plot the performance curves based on the measured test data. Incomparing these data it is important to remember the that manufacturers's published data is, presumably, based on fan performance alone; i.e., without the flow restrictions imposed by the pipe and couplings used to simulate a simple system. For this reason the flow data published by the manufacturers would be expected to be higher than the data produced by these tests. The most significant differences appear, as anticipated, in the comparison of test data with published data based on unrestricted 6" fan inlets. Figures 1 - 3 indicate the fan performance curves based on these test data.

Fan	Flow @	---------- Pressure (inches WC) ----------								Pressure
Model	0" WC	0.5	0.75	1.0	1.25	1.5	2.0	2.5	3.0"	@ 0 CFM
	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(" WC)
XP101	120	108	88	63	36	8				1.58
	125	*90*	--	*40*	--	--				*1.2*
XP151	134	128	102	69	32	3				1.52
	180	*140*	--	*80*	--	*5*				*1.6*
XP201	112	98	80	65	43	21				1.78
	150	*110*	--	*75*	--	*40*				*2.0*
XR161	133	115	72	45	26	10				1.72
	215	*160*	--	*100*	--	*45*				*1.9*
XR261	155	165	115	79	52	36	5			2.10
	250	*185*	--	*115*	--	*50*				*1.9*

Table 2: Test Data vs. Catalog Reference Data -- Pressure/Flow for XP/XR Series Fans
(catalog reference data in *italics*)

Fan	Flow @	---------- Pressure (inches WC) ----------								Pressure
Model	0" WC	0.5	0.75	1.0	1.25	1.5	2.0	2.5	3.0"	@ 0 CFM
	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(cfm)	(" WC)
GP201	78	70	67	61	52	44	21			2.04
	--	--	--	*82*	--	*58*	*5*			*2.0*
GP301	84	80	70	67	62	55	40			2.47
	--	--	--	*92*	--	*77*	*45*	*10*		*2.6*
GP501	92	90	85	80	75	70	62	42	12	4.21
	--	--	--	*95*	--	*87*	*80*	*70*	*57*	*4.2*

Table 3: Test Data vs. Catalog Reference Data -- Pressure/Flow Data for GP Series Fans
(catalog reference data in *italics*)

Fan Model	Flow @ 0" WC (cfm)	Pressure (inches WC) 0.5 (cfm)	0.75 (cfm)	1.0 (cfm)	1.25 (cfm)	1.5 (cfm)	2.0 (cfm)	2.5 (cfm)	3.0" (cfm)	Pressure @ 0 CFM (" WC)
FR100	110	82	40							0.92
	108	--	*25*	--	--	--				*.86*
FR150	172	187	158	122	85	39				1.95
	243	--	*151*	*114*	*82*	*18*				*1.56*
HP190	136	132	112	90	70	45	5			2.08
	173	--	*114*	*98*	*73*	*48*				*1.98*
HP220	210	--	--	210	180	152	75	15		2.59
	345	--	*237*	*207*	*169*	*142*	*59*			*2.46*
ECL452	134	120	107	76	31					1.26
	140	--	*85*	*61*						*1.19*

Table 4: Test Data vs. Catalog Reference Data -- Pressure/Flow Data for FR/HP/ECL Fans (catalog reference data in *italics*)

Table 5 compares test data with published data for electric consumption, using only high and low end data for comparative purposes:

Fan	Published range (watts)	Test range (watts)
XP101	40 - 49	30 - 40
XP151	45 - 60	40 - 55
XP201	45 - 65	40 - 60
XR161	48 - 75	40 - 60
XR261	65 - 105	75 - 100
GP201	40 - 60	60 - 80
GP301	55 - 90	60 - 100
GP501	60 - 140	70 - 140
FR100	34 -44	40 - 50
FR150	76 - 93	60 - 80
FR175		80 - 135
HP190	60 - 92	50 - 80
HP220	85 - 147	80 - 140
ECL452	87 -110	70 - 100
RAM2	< 90	60 - 80

Table 5: Comparative electric energy consumption

CONCLUSIONS

The test of radon fans manufactured by different companies on a single test apparatus designed to simulate a simple radon system provides a uniform basis of comparison by which radon mitigators can evaluate the relative performances characteristics of different fans. Discrepancies between these data and the published data in radon supply catalogs, particularly in low-pressure/high-flow configurations, clearly highlights the value of developing an independent, uniform methodology for testing radon control equipment.

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APPENDICES

Measurement Instruments

This study was designed to make measurements that had a measurement error less than 5%. In order to accomplish this the instrument used to make the pressure readings was a digital micro-manometer capable of reading tenths of a Pascal (0.00025" WC) and a instrument error of less than 1%. This monitor included automatic zeroing, two channels to allow easy measurement of pressure drop and airflow, as well as having a setting that averaged 10 seconds of measurements. This instrument was calibrated the week before the study began. In order to confirm that it had been calibrated properly an EDM digital micro-manometer was sent to a different manufacturer to be calibrated. Both instruments were then compared by having them measure the same pressure difference as the pressure was varied in test piping. The instruments had comparable measurement readings throughout the range of pressures used in this study.

All air flow speeds in this study are either feet per minute air speed inside the pipe or the actual cubic feet per minute (cfm). There are a number of methods used to determine the airflow speed inside a pipe. The measurement method that is most widely recognized is the use of a Pitot tube. This instrument is a tube within a tube that simultaneously measures the total airflow pressure and the sidewall static pressure. This allows the sidewall static pressure to be used as the reference pressure thus automatically subtracting it from the total pressure. The remaining pressure is referred to as the velocity pressure. The ASHRAE fundamentals handbook reports the precision of Pitot tube measurements as between 1 and 5%. The airflow within a pipe however is not uniform. In order to minimize the effect of different airflow's within a pipe a Pitot tube flow grid was placed inside a section of 4" pvc piping. This allowed for a simplier and more consistent measurement throughout the study. All airflow measurements were made with this 4" flow grid that always had greater than ten pipe diameters of straight piping (40") both in front and behind the flow grid.

Calibrating the Flow Grid

The pressure drop taking place across a fitting or piping varies with the airspeed within the piping. It is of course critical to know the airflow as accurately as possible in order to define the correct calibration constant for each fitting or length of piping. A number of quality assurance checks were made to ensure this by careful placement of the airflow measuring device, calibration of the measuring equipment and exacting measurements. All pressure measurements made in this study were in units of Pascals and then converted to inches of water. One inch of water column is the equivalent pressure of 248.9 Pascals.

After the flow grid was installed inside the pipe it was re-calibrated in order to provide accurate airflow measurements. This calibration factor was obtained by carefully making a series of transverse Pitot tube measurements in a 10 foot long straight section of 4" piping. The exact procedure recommended by ASHRAE fundamentals was used to make this re-calibration. This procedure defines sixteen transverse locations in the pipe where the Pitot measurements are made. A small jig was set up to make sure the Pitot tube was inserted properly into the pipe and each velocity pressure measurement was averaged over ten second readings. The corresponding flow grid velocity pressure was checked several times during these measurements to ensure that it had not changed because of a variation in the fan speed. The Pitot tube velocity pressure measurements are then averaged to determine the actual cfm air flow using the following formula.

$cfm = [\,1097 * \sqrt{ptvp/ad}\,] * sa$
ptvp = average velocity pressure in inches of water from transverse Pitot tube measurement
ad = air density lbs/cf
(0.075 if unknown)
sa = area of duct in square feet

Formula 1 - CFM determination from transverse Pitot tube reading

Air Flow Measurements

The calibration factor for the flow grid is then determined from the velocity measurements of the flow grid and the cfm results using Formula 1. The velocity pressure readings from this flow grid were used exclusively to determine the actual airflow during the measurement of pressure drop across the pipe, fitting or fittings. The formula for determining the cfm from the flow grid is given below in Formula 2.

$cfm = fgcf * \sqrt{fgvp/ad}$
fgvp = flowgrid velocity pressure in inches of water
ad = air density lbs/cf
(0.075 if unknown)
fgcf = flowgrid calibration factor

Formula 2 - CFM determination from flow grid

Static Pressure Readings

The pressure drop measurement across each pipe fitting or length of pipe was made using the static pressure port of two Pitot tubes. Each Pitot tube was inserted into the center of the pipe on opposite sides of the fitting or a known distance between straight ducting. The static pressure port of the Pitot tube was always facing the fitting or length of pipe being tested so that no additional resistance was caused by the Pitot tube itself. The digital micro-manometer had the reference port always connected to the Pitot tube farthest from the fan and the signal port connected to the Pitot tube closest to the fan so that the pressure difference caused by the airflow resistance in the pipe was measured directly as a positive pressure. It was determined initially that four feet from each side of the fitting was a enough distance to allow measurement of the full pressure drop from the fitting. The true pressure drop of the fitting or fittings was calculated by taking the total pressure drop and subtracting the calculated pressure drop for that particular airflow from the straight run of ducting on each side of the fitting and any additional straight ducting that was placed between two fittings.

The pressure drop of straight sections of ducting was measured by laying out about 30 feet of the pipe with a minimal amount of joints. The Pitot tubes were then placed at the farthest distance apart while still maintaining at least 10 pipe diameters away from any disturbance on either end of the ducting. This allowed the measurement of the pressure drop across approximately 23 feet with typically two pipe joints in between. Any seams in the piping that were not totally airtight were sealed with duct tape. All test holes used for the measurements in the piping were sealed when not in use. The Pitot tube hole was also the exact size of the Pitot tube to minimize any additional loss. Each Pitot tube was clamped in its position and checked with a square to ensure it was orient in the correct position. All angled fittings were also checked to ensure that their angle was appropriate to the fitting.

Each pressure drop measurement of pipe length or fitting was tested at five or six different airflow's. The measurement sequence was to measure the airflow first by measuring the flow grid velocity pressure with a series of 10 second average readings. The digital micro-manometer was then switched to read the pressure drop across the pipe or fitting(s) for 10 second averages. The digital micro-manometer was then switched back to the airflow grid velocity pressure and 10 second averages were again obtained to confirm that the airflow had not changed. If duplicate airflow or pressure readings varied greater than one or two Pascals, the measurements were repeated. This procedure was repeated for each airflow and for each fitting or pipe. In all over 1500 10 second pressure readings were made in order to accurately determine the pressure drop of the components tested.

Each set of 10 second average pressure drop or flow grid velocity pressure readings for each flow was then averaged. These average readings were then entered into a spreadsheet program. The air density used in the airflow calculation at each reading was determined by measuring the temperature and humidity at the testing location and then calling the nearest local airport to obtain the current barometric pressure. This factors were then entered into a slide rule used for obtaining the air density that is supplied by Dwyer Instruments. Each of the changes in weather can influence the reading by a few percent. Below is a chart of the differences that can be expected in the readings as the weather varies from the standard. As can be seen from the Table 1 below, the changes in weather factors cause only a slight difference.

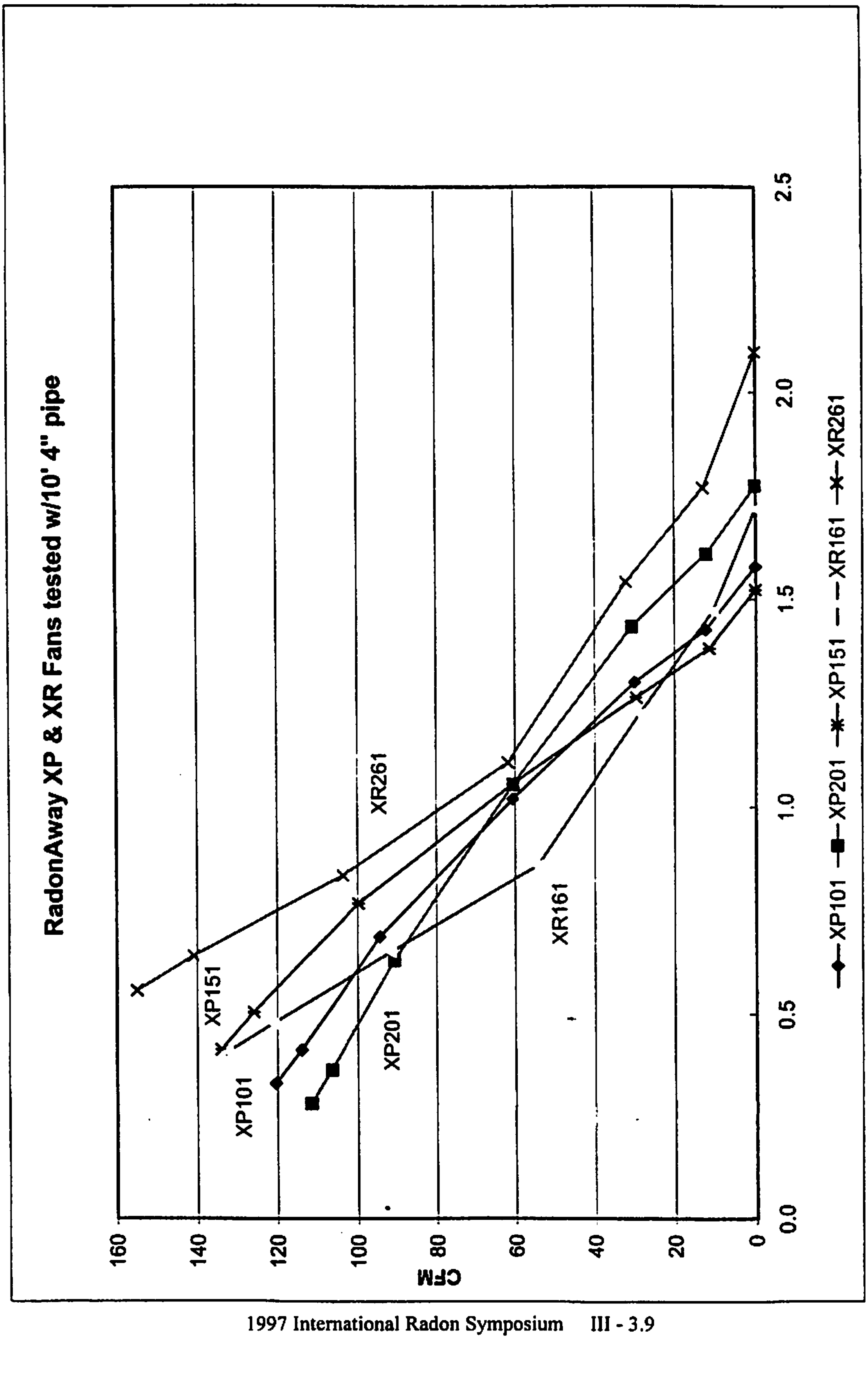
The standard air density of 0.075" is based on 30.0" of barometric pressure at 70 degrees and 20% relative humidity.
· If humidity is actually 50% versus 20% the measurement will be biased low 0.2%
· If humidity is actually 80% versus 20% the measurement will be biased low 0.45%
· If Barometric pressure is 31.0" instead of 30.0" the measurement will be biased high 1.6%
· If Barometric pressure is 29.0" instead of 30.0" the measurement will be biased low 1.7%
· If temperature is actually 80 degrees versus 70 degrees the measurement will be biased low 1.0%
· If temperature is actually 60 degrees versus 70 degrees the measurement will be biased high 0.9%

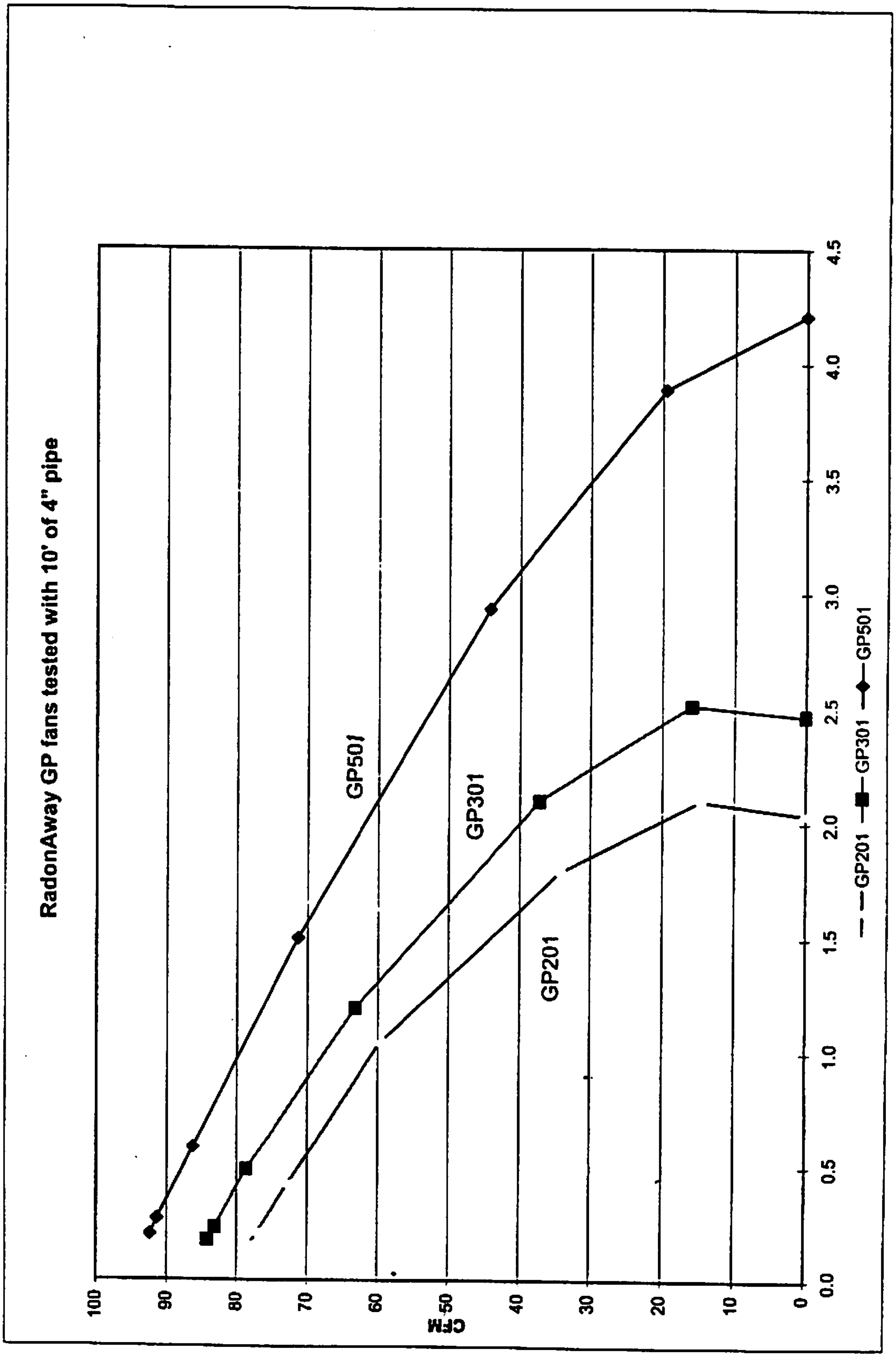
Appendix Table 1 - Small airflow measurement variation due to weather or altitude

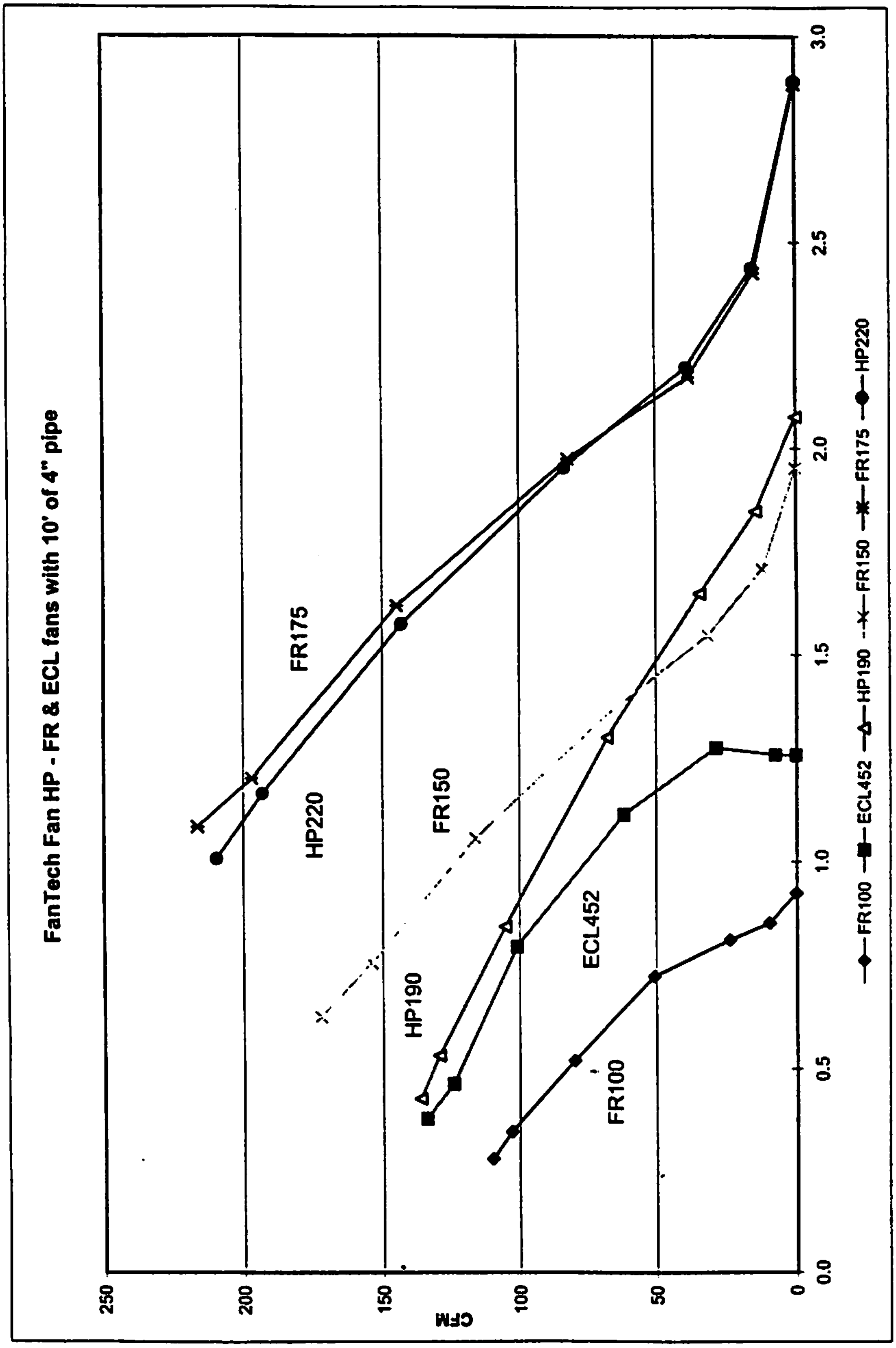
1. The radon catalogs surveyed were: Infiltec, PO Box 1125, Waynesboro, VA, 22980; Professional Discount Supply, 525 E. Fountain Blvd, Suite 201, Colorado Springs, CO, 80903; RadonAway, 187 Neck Road, Ward Hill, MA 01835; Radon Control, Inc, 511 Industrial Blvd, Carmel, IN, 46032; Safe-Aire, 162 E. Chestnut Street, Canton, IL, 61520.

   The fans listed in these catalogs were:
   FanTech FR100, FR125*, FR150, FR160, FR200, FR225, FR250, ECL452, HP190, HP220; RadonAway XP101, XP151, XP201, XR161, XR261, GP201, GP301, GP401, GP501, GP500, HS2000, HS3000, HS5000; Rosenberg R100, R150, R200, R200L, Turbo5, Turbo6, ACP100, ACP125, ACP150, ACP200, ACP250

2. Published fan data for XP/GP series fan are from the RadonAway 1997 Catalog; data for the FR/HP/ECL series fans are from the RCI 1996-1997 Catalog.


RadonAway XP & XR Fans tested w/10' 4" pipe
CFM
160
140
120
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
XP151
XR261
XP101
XP201
XR161
XP101 XP201 XP151 XR161 XR261


RadonAway GP fans tested with 10' of 4" pipe
CFM
0
10
20
30
40
50
60
70
80
90
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
GP501
GP301
GP201
GP201
GP301
GP501



FanTech Fan HP - FR & ECL fans with 10' of 4" pipe
CFM
0
50
100
150
200
250
0.0
0.5
1.0
1.5
2.0
2.5
3.0
FR175
HP220
FR150
HP190
ECL452
FR100
FR100
ECL452
HP190
FR150
FR175
HP220