Determining static vacuum pressure required to ventilate Opti Carousel racks at various flow rates

Eric Corell

Objective

Due to changes in filter design, cage configuration, and newly introduced products and accessories, we intend to measure the static pressure required to ventilate ACS Opti Carousel racks at a range of flow rates encompassing the minimum and recommended flow rates as set forth in ACS literature. This analysis will be performed on new racks with the most current lineup of standard accessories.

Equipment

- ACS Optimice Rack (Part Number C89100P)
- ACS Optirat Rack (Part Number C86100P)
- ACS Optirat Plus Rack (Part Number CP86100P)
- Quatro Clean Air SPB 560 Filtered Blower
- ACS Exhaust Damper Assembly, two units used (Part Number M79190)
- Modified Valterra Clear-View Adapter to include
    - Sensirion SDP 610 differential pressure sensor with laptop for data logging.
- Modified Valterra Clear-View Adapter to include
    - Extech 407123 Hot Wire Thermo-Anemometer

Method

Apparatus Construction

Two Valterra Clear-View Adapters were modified to build apparatuses for this analysis. One hole, perpendicular to the flow path, was drilled in the wall of each Clear-View Adapter; one of the holes was 3/8”, and the other was 1/2” in diameter.

A 6” length of flexible vinyl hose was sealed into the 3/8” hole with 1/4” of its length protruding into the interior of the adapter. The exterior end of the hose was connected to one of the two ports on the differential pressure sensor; the other port was left open to exposure to ambient atmospheric pressure.

The probe of the Extech Anemometer was inserted through the 1/2” hole and positioned so the hot wire itself was exactly centered in the flow path. Its rotation was also scrutinized to ensure the flow passage through the probe was aligned parallel to the flow path through the Clear-View Adapter. The probe was sealed in place with tape and secured with a shaft collar.

Procedure

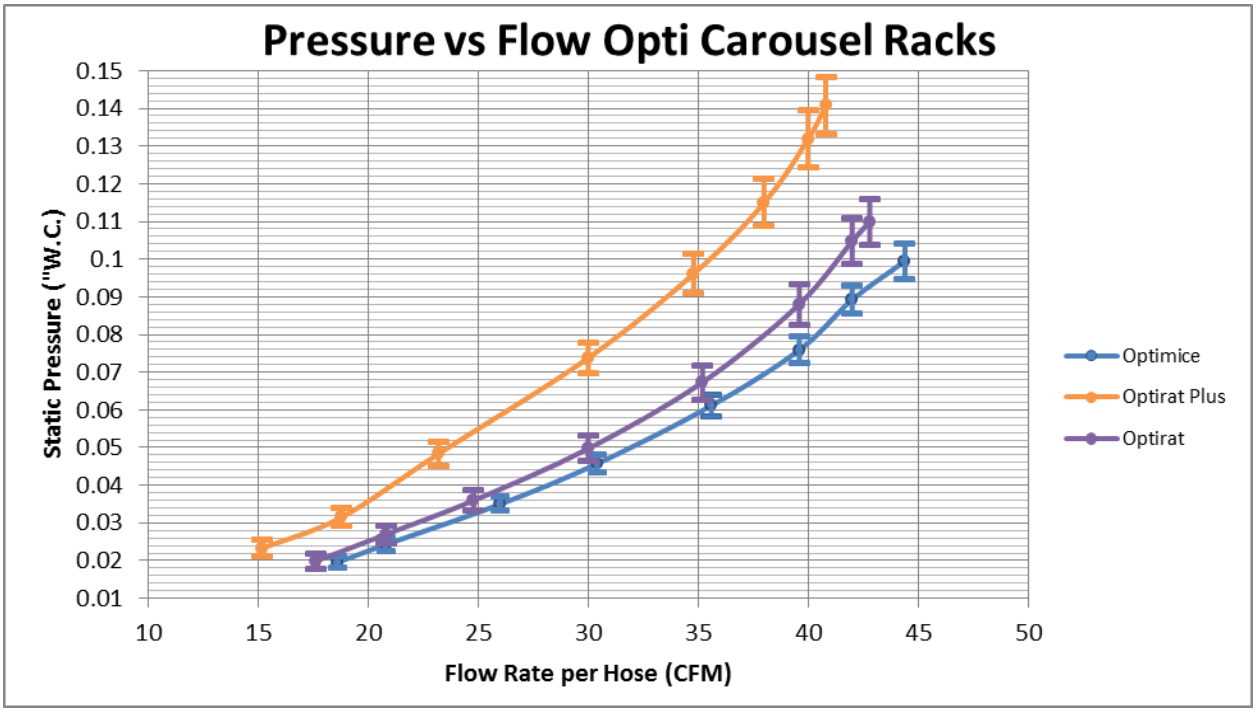
The inlet ducting of the Quatro SPB 560 was equipped with a 3" diameter wye fitting. This allows the connection of two standard ACS exhaust hoses between the various Opti Carousel racks and the SPB 560. An Exhaust Damper Assembly was connected to each of the inlets at the wye fitting to allow for fine adjustment of airflow through each hose; the dampers were initially set to be fully open. The modified Clear-View Adapters (with airflow and pressure sensors) were connected in line with the exhaust hoses at the top of the rack with the pressure sensing adapter connected to one exhaust port and the airflow sensing adapter connected to the other.

The exhaust hoses were connected between the rack and the SPB 560, the unit was switched on, and airflow through both hoses was measured at five different fan speeds. The hoses were swapped back and forth between two sensor-equipped adapters on the top of the rack to properly make the measurements under working conditions (both hoses were connected to the rack when measurements were taken for each). The dampers were then adjusted to equally balance the airflow through the two hoses at any fan speed. Due to turbulence and general noise in the system, a 100% perfect balance is not possible or applicable; however, the flow rates were balanced well within the system noise and margin of error of the instrument.

The fan speed was then dialed down to the lowest setting, and the pressure sensor's data logger was started, taking measurements every 0.1 seconds. Once stable, an airflow measurement at that fan speed was recorded. After roughly 10 seconds, the fan speed was incremented by roughly $1/8^{th}$ of the total speed range, waiting until stable readings were present at each, and airflow measurements were recorded once stabilized. The SPB 560 was allowed to run at each fan speed for at least 10 seconds before proceeding to the next. This process continued until the fan speed was at its maximum. Ideally, this should result in eight discrete flow rates with corresponding pressure data for each.

As mentioned earlier, there was a considerable amount of noise in the pressure data; therefore, the numerous pressure readings (100+) for each flow rate were analyzed statistically, and an arithmetic mean and standard deviation were determined.

Data



All airflow values listed refer to flow rate per exhaust hose and are expressed in cubic feet per minute (CFM); double these values to get total flow. All pressures are expressed in inches of water (”W.C.)

Optimice			**Optirat *Plus***			**Optirat**		
Flow	Press	± (SD)	Flow	Press	± (SD)	Flow	Press	± (SD)
18.6	0.01955	0.00157	15.2	0.02330	0.00220	17.6	0.01986	0.00198
20.8	0.02427	0.00183	18.8	0.03155	0.00233	20.8	0.02698	0.00235
26	0.03501	0.00185	23.2	0.04836	0.00315	24.8	0.03599	0.00284
30.4	0.04572	0.00244	30	0.07377	0.00418	30	0.04972	0.00336
35.6	0.06114	0.00284	34.8	0.09615	0.00518	35.2	0.06736	0.00455
39.6	0.07591	0.00348	38	0.1150	0.00627	39.6	0.08806	0.00539
42	0.08927	0.00363	40	0.1319	0.00748	42	0.1048	0.00592
44.4	0.09949	0.00467	40.8	0.1407	0.00768	42.8	0.1099	0.00595

Static pressures at minimum and recommended literature flow rates:

	Optimice		**Optirat *Plus***		**Optirat**	
	Flow per Hose (CFM)	Static Pressure (”W.C.)	Flow per Hose (CFM)	Static Pressure (”W.C.)	Flow per Hose (CFM)	Static Pressure (”W.C.)
Minimum	20	0.022±0.0017	28	0.066±0.0039	28	0.044±0.0032
Recommended	30	0.045±0.0024	41	0.141±0.0077	41	0.097±0.0057

Notes/Discussion

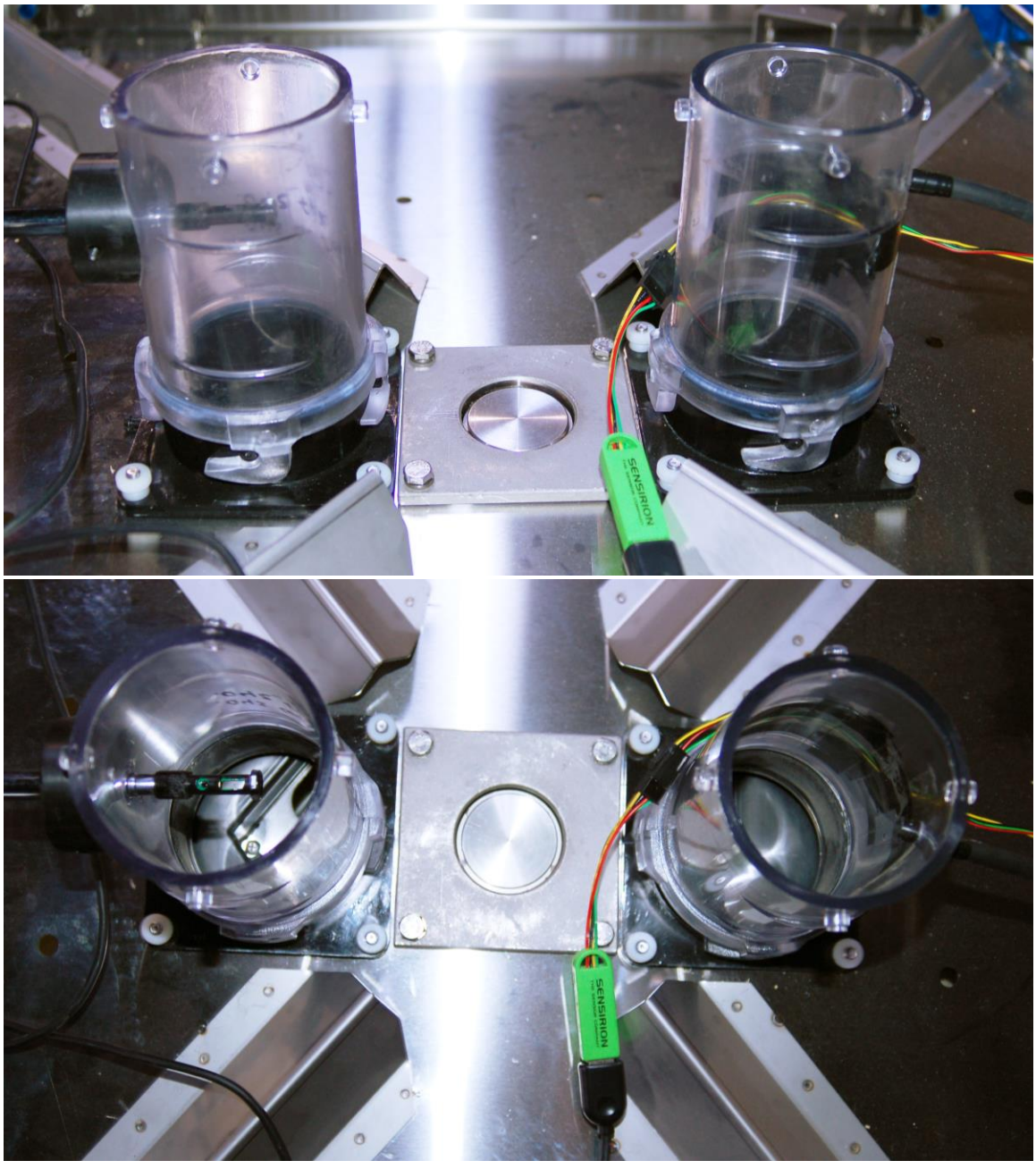
One potential concern that should be addressed is the restriction of free area through the anemometer-equipped Clear-View adapter; however, the probe as it is positioned only restricts free area by roughly 0.25 sq-in. Of the 7.1 sq-in available, this restriction represents a 3.5% reduction in free area. Furthermore, a large portion of the closed area of the probe exists closer to the passage walls where air velocity is lower, and therefore, the effect of restricting free area in this region will be smaller than if the restriction occurred in the center of the passage. All told, the <3.5% uncertainty caused by restricted area is well within the system noise, which generally ranges from 5-10%. On the other hand, the static pressure hose in the other Clear-View adapter restricts free area by roughly 0.1 sq-in, and this occurs entirely within 0.25" from the passage wall; the effect of this restriction would be considered entirely negligible.

The above discussion of free area restriction is only applicable in addressing suspicions that the airflow was not truly balanced between the two hoses. The anemometer-equipped apparatus was meticulously calibrated as an assembly in order to accurately derive volume flow (CFM) from linear flow (ft/min); the restricted free area is fully incorporated into this calibration.

From the data, we notice that the static pressure measurements differ slightly from the values listed in the ventilation section of the ACS technical sheet for OptiMICE. It is important to note, however, that static pressure measurements can vary considerably depending on the location within the system at which the measurements were made, the prevailing atmospheric conditions (e.g. barometric pressure, temperature, relative humidity, etc.), and especially the age (in terms of cage change cycles) of the cage air filters. Because of this tendency for variables to significantly affect the working static pressure, these literature values are to be interpreted only as general capacity requirements for the HVAC system in a proposed facility and not as a metric of proper or improper ventilation performance. Pressure measurements that lie drastically outside of the literature values, however, could be indications of improper performance.

Appendix

I. Photos of apparatuses and equipment setup

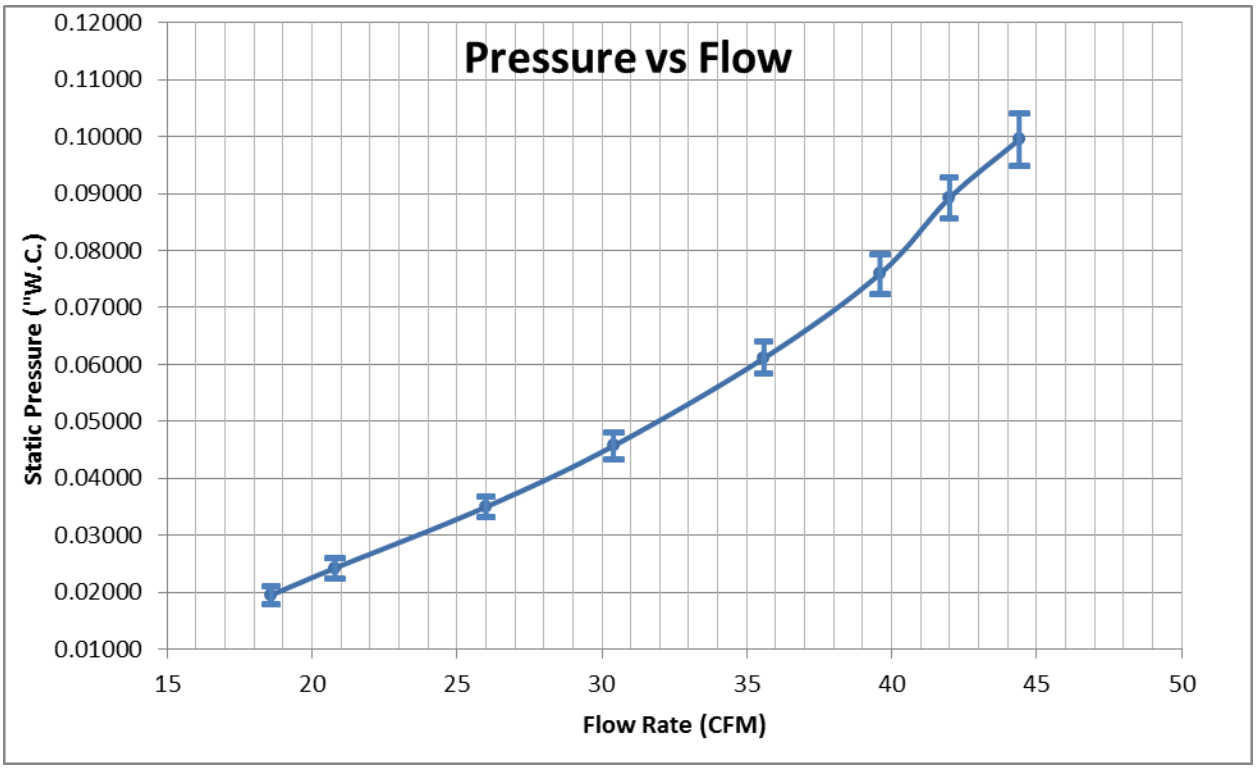


Modified Clear-View Adapters: Anemometer – Extech 407123 (Left), Pressure sensor – SDP610 (Right)
Exhaust hoses removed for improved visibility

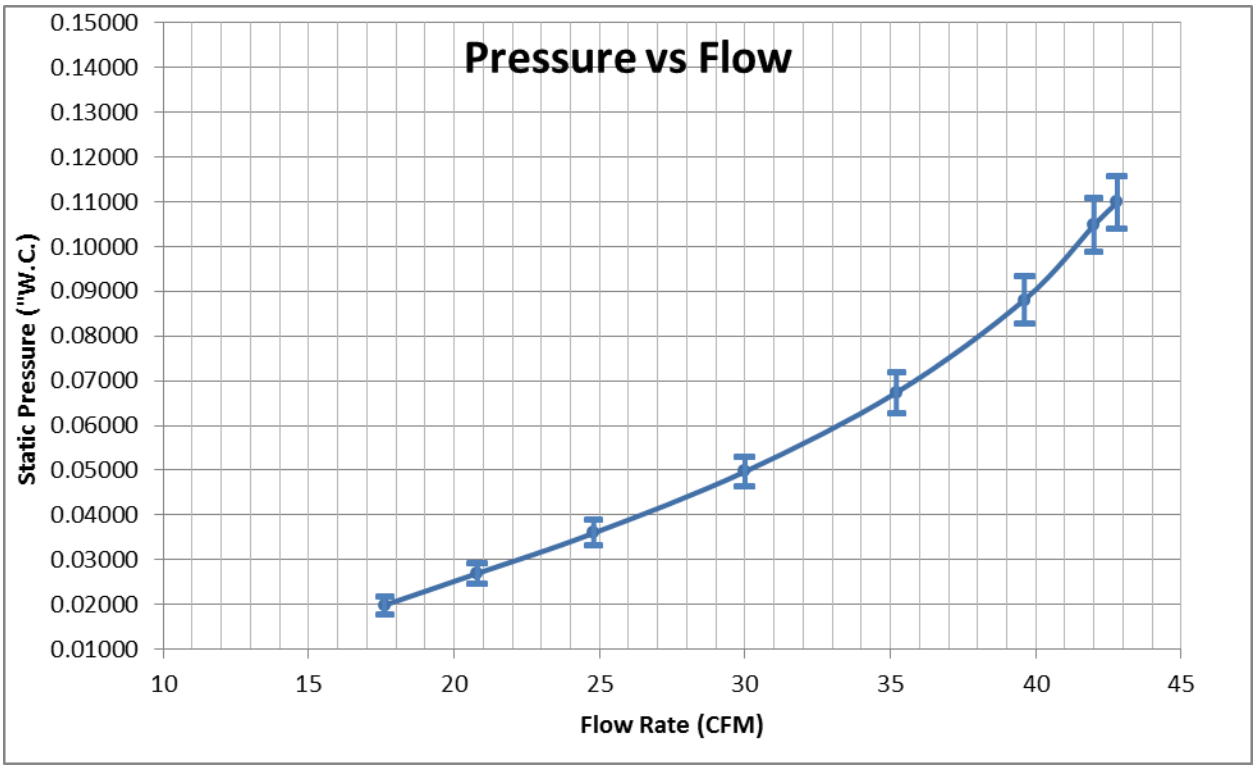
Quatro SPB 560 Filtered Air Handler – with wye fitting for dual hose connections

II. Graphs and raw data

Optimice Pressure Tests								
Airspeed (ft/min)	465	520	650	760	890	990	1050	1110
Average Pressure	0.01955	0.02427	0.03501	0.04572	0.06114	0.07591	0.08927	0.09949
SD	0.00156	0.00183	0.00185	0.00244	0.00284	0.00348	0.00363	0.00466
Airflow (CFM)	18.6	20.8	26	30.4	35.6	39.6	42	44.4



Optirat Pressure Tests								
Airspeed (ft/min)	440	520	620	750	880	990	1050	1070
Average Pressure	0.01986	0.02697	0.03599	0.04972	0.06736	0.08806	0.10479	0.10989
SD	0.00198	0.00235	0.00283	0.00336	0.00455	0.00539	0.00592	0.00595
Airflow (CFM)	17.6	20.8	24.8	30	35.2	39.6	42	42.8



Optirat Plus Pressure Tests								
Airspeed (ft/min)	380	470	580	750	870	950	1000	1020
Average Pressure	0.02330	0.03155	0.04836	0.07377	0.09615	0.11495	0.13190	0.14071
SD	0.00220	0.00233	0.00315	0.00418	0.00518	0.00627	0.00748	0.00768
Airflow (CFM)	15.2	18.8	23.2	30	34.8	38	40	40.8