# Airflow Measuring System Using Piezometer Ring

**IM-130**
January 2017

**General Installation, Operation and Maintenance Instructions For Aerovent Products**

Aerovent now offers an air measuring device as an option on centrifugal fans. It is based on the principle of a flow nozzle. The inlet cone of the fan is used as the flow nozzle. By measuring the pressure drop through the inlet cone, the flow can be calculated. The system consists of a piezometer ring mounted in the throat and a static pressure tap mounted on the face of the inlet cone. A differential pressure transducer and a digital display can be provided. The display must be capable of performing the square root function in order to read out in CFM directly. By testing fans in the laboratory, Aerovent was able to determine flow coefficients for various fan types. The flow coefficients were combined to give the equations listed below by fan type. Based on testing performed in Aerovent's laboratory, the accuracy of the system was determined to be +/- 5%.

The pressure drop is measured from the tap located on the face of the funnel to the piezometer ring in the throat. The inlet tap is connected to the high-pressure side of the transducer and the piezometer ring is connected to the low-pressure side.

## Measurement of Airflow

The equations below are accurate for flow estimation for flows from 40% to 100% of wide-open volume. According to testing done previously at Aerovent, several factors affect the accuracy of this method of determining flow. The equations below assume the following:

- There are no vanes or other obstructions in or near the inlet
- Even flow entering the funnel (no pre-swirl)
- Standard wheel to inlet cone overlap
- Accurate determination of air density at the inlet
- Free inlet (consult Aerovent for ducted inlet factors)

### Non-Standard Density Method

One of the following equations is used to measure the flow:

$$ACFM = C1 * A * \sqrt{(\Delta P/\rho)}$$

where: A = Actual inlet funnel throat area (square feet) - from tables on pages 2 and 3
$\Delta P$ = The differential in static pressure from the piezometer ring and the front pressure tap (inches w.g.)
$\rho$ = Air density (pounds mass/cubic foot)
C1 = Value from Table 1 below

### Standard Density Method

The equations can be simplified by assuming standard density and assuming funnel dimensions match drawing dimensions. The following tables show the factor (F) for each fan size and type. The equation then becomes the following:

For standard air ($\rho$ = 0.075 lb/ft$^3$):

$$ACFM = F\sqrt{\Delta P}$$

where: F = factor from tables on pages 2 and 3
$\Delta P$ = The differential in static pressure from the piezometer ring and the front pressure tap (inches w.g.)

**Table 1: C1 Values**

| Product | C1 Free Inlet | C1* Ducted Inlet |
|---|---|---|
| CPLFN/CPLQN (Arr. 1 or 4), Sizes 122-165 | 753.06 | 794.06 |
| CPLFN/CPLQN (Arr. 1 or 4), Sizes 122A-165A | 887.78 | 949.49 |
| CPLFN/CPLQN (Arr. 1 or 4), Sizes 182-982 | 692.03 | 740.14 |
| CPLF/CPLQ (Arr. 3), Sizes 122-165 | 726.39 | 765.94 |
| CPLF/CPLQ (Arr. 3), Sizes 122A-165A, 182-982 | 856.34 | 915.87 |
| CPLF/CPLQ (Arr. 3), Sizes 182-982 | 667.52 | 713.93 |
| CB/CBA SWSI | 735.42 | 786.56 |
| CB/CBA DWDI | 1470.84 | 1573.12 |
| AFE | 735.42 | 753.56 |
| AMX | 696.00 | 735.83 |
| CAE-SW ** | 720.40 | 735.80 |
| CAE-DW** | 1440.80 | 1471.60 |
| CPG | 753.06 | 794.06 |
| MH (Std. Inlet Bell) | 913.33 | 997.49 |

* Values for ducted C1 factors are based on duct diameter matching standard inlet collar diameter.
** CAE sizes smaller than 182 use CB\CBA Factors.

**Table 2: CPLF/CPLQ (Arrangement 3), CPLFN/CPLQN (Arrangement 1 & 4)**

| Size | CPLF/ CPLQ Free Inlet F | CPLFN/ CPLQN CPL-Series Free Inlet F | CPLF/CPLQ Ducted Inlet F | CPLFN/ CPLQN CPL-Series Ducted Inlet F | A |
|---|---|---|---|---|---|
| 122 | 911.46 | 944.92 | 961.07 | 996.36 | 0.344 |
| 122A, 122MK2 | 1194.48 | 1238.33 | 1277.52 | 1324.41 | 0.382 |
| 150 | 1163.68 | 1206.40 | 1227.04 | 1272.08 | 0.439 |
| 150A, 150MK2 | 1779.21 | 1844.54 | 1902.90 | 1972.75 | 0.569 |
| 165 | 1464.80 | 1518.58 | 1544.56 | 1601.26 | 0.552 |
| 165A, 165MK2 | 2138.81 | 2217.33 | 2287.49 | 2371.46 | 0.684 |
| 182 | 1757.39 | 1821.92 | 1879.58 | 1948.58 | 0.721 |
| 200 | 2108.38 | 2185.80 | 2254.97 | 2337.76 | 0.865 |
| 222 | 2617.81 | 2713.93 | 2799.81 | 2902.60 | 1.074 |
| 245 | 3168.67 | 3285.02 | 3388.97 | 3513.39 | 1.300 |
| 270 | 3856.03 | 3997.61 | 4124.12 | 4275.53 | 1.582 |
| 300 | 4770.07 | 4945.21 | 5101.71 | 5289.01 | 1.957 |
| 330 | 5757.23 | 5968.62 | 6157.51 | 6383.56 | 2.362 |
| 365 | 7032.01 | 7290.21 | 7520.92 | 7797.03 | 2.885 |
| 402 | 8555.41 | 8869.55 | 9150.23 | 9486.16 | 3.510 |
| 445 | 10444.42 | 10827.92 | 11170.58 | 11580.68 | 4.285 |
| 490 | 12669.80 | 13135.01 | 13550.69 | 14048.16 | 5.198 |
| 542 | 15541.11 | 16111.75 | 16621.62 | 17231.84 | 6.376 |
| 600 | 19004.71 | 19702.52 | 20326.03 | 21072.24 | 7.797 |
| 660 | 22994.79 | 23839.12 | 24593.53 | 25496.41 | 9.434 |
| 730 | 28128.04 | 29160.84 | 30083.67 | 31188.11 | 11.54 |

**Table 3: CB/CBA**

| Size | SWSI Free Inlet F | DWDI Free Inlet F | SWSI Ducted Inlet F | DWDI Ducted Inlet F | A |
|---|---|---|---|---|---|
| 105 | 641.87 | 1283.74 | 686.51 | 1373.01 | 0.239 |
| 122 | 872.90 | 1745.81 | 933.61 | 1867.21 | 0.325 |
| 135 | 1058.21 | 2116.41 | 1131.79 | 2263.58 | 0.394 |
| 150 | 1305.20 | 2610.39 | 1395.96 | 2791.92 | 0.486 |
| 165 | 1587.21 | 3174.41 | 1697.58 | 3395.16 | 0.591 |
| 182 | 1936.99 | 3873.98 | 2071.69 | 4143.38 | 0.721 |
| 200 | 2321.58 | 4643.16 | 2483.02 | 4966.04 | 0.865 |
| 222 | 2883.02 | 5766.04 | 3083.50 | 6167.00 | 1.074 |
| 245 | 3491.62 | 6983.24 | 3734.42 | 7468.84 | 1.300 |
| 270 | 4247.77 | 8495.55 | 4543.16 | 9086.32 | 1.582 |
| 300 | 5254.03 | 10508.05 | 5619.38 | 11238.86 | 1.957 |
| 330 | 6342.73 | 12685.46 | 6783.80 | 13567.59 | 2.362 |
| 365 | 7747.97 | 15495.94 | 8286.75 | 16573.50 | 2.885 |
| 402 | 9426.99 | 18853.98 | 10082.53 | 20165.06 | 3.510 |
| 445 | 11507.43 | 23014.86 | 12307.64 | 24615.28 | 4.285 |
| 490 | 13957.43 | 27914.86 | 14928.01 | 29856.02 | 5.198 |
| 542 | 17121.05 | 34242.10 | 18311.62 | 36623.24 | 6.376 |
| 600 | 20938.50 | 41877.00 | 22394.53 | 44789.06 | 7.797 |
| 660 | 25334.37 | 50668.73 | 27096.08 | 54192.16 | 9.434 |
| 730 | 30991.88 | 61983.75 | 33147.00 | 66294.01 | 11.54 |
| 807 | 37901.44 | 75802.87 | 40537.05 | 81074.09 | 14.11 |
| 890 | 46079.00 | 92158.01 | 49283.27 | 98566.54 | 17.16 |
| 982 | 56192.01 | 112384.00 | 60099.52 | 120199.04 | 20.93 |

**Table 4: CAE-SW/CAE-DW**

(Sizes smaller than 182 use Table 3: CB\CBA)

| Size | SWSI Free Inlet F | DWDI Free Inlet F | SWSI Ducted Inlet F | DWDI Ducted Inlet F | A |
|---|---|---|---|---|---|
| 182 | 1896.61 | 3793.22 | 1937.16 | 3874.31 | 0.721 |
| 200 | 2275.41 | 4550.82 | 2324.05 | 4648.10 | 0.865 |
| 222 | 2825.19 | 5650.38 | 2885.58 | 5771.16 | 1.074 |
| 245 | 3419.69 | 6839.38 | 3492.79 | 6985.58 | 1.300 |
| 270 | 4161.50 | 8322.99 | 4250.46 | 8500.91 | 1.582 |
| 300 | 5147.95 | 10295.89 | 5257.99 | 10515.99 | 1.957 |
| 330 | 6213.31 | 12426.62 | 6346.13 | 12692.26 | 2.362 |
| 365 | 7589.08 | 15178.15 | 7751.31 | 15502.62 | 2.885 |
| 402 | 9233.16 | 18466.31 | 9430.53 | 18861.07 | 3.510 |
| 445 | 11271.82 | 22543.63 | 11512.77 | 23025.55 | 4.285 |
| 490 | 13673.49 | 27346.98 | 13965.79 | 27931.57 | 5.198 |
| 542 | 16772.25 | 33544.50 | 17130.79 | 34261.59 | 6.376 |
| 600 | 20510.23 | 41020.47 | 20948.68 | 41897.36 | 7.797 |
| 660 | 24816.41 | 49632.82 | 25346.91 | 50693.82 | 9.434 |
| 730 | 30356.30 | 60712.61 | 31005.23 | 62010.46 | 11.540 |
| 807 | 37116.76 | 74233.52 | 37910.21 | 75820.42 | 14.110 |
| 890 | 45139.88 | 90279.75 | 46104.83 | 92209.66 | 17.160 |
| 982 | 55056.97 | 110113.94 | 56233.92 | 112467.85 | 20.930 |

**Table 5: AMX**

| Size | Free Inlet F | Ducted Inlet F | A |
|---|---|---|---|
| 150 | 1832.36 | 1937.23 | 0.721 |
| 165 | 2198.32 | 2324.14 | 0.865 |
| 182 | 2729.48 | 2885.70 | 1.074 |
| 200 | 3303.84 | 3492.93 | 1.300 |
| 222 | 4020.52 | 4250.63 | 1.582 |
| 245 | 4973.55 | 5258.21 | 1.957 |
| 270 | 6002.82 | 6346.39 | 2.362 |
| 300 | 7331.98 | 7751.62 | 2.885 |
| 330 | 8920.36 | 9430.92 | 3.510 |
| 365 | 10889.96 | 11513.24 | 4.285 |
| 402 | 13210.27 | 13966.36 | 5.198 |
| 445 | 16204.06 | 17131.49 | 6.376 |
| 490 | 19815.41 | 20949.54 | 7.797 |
| 542 | 23975.70 | 25347.94 | 9.434 |
| 600 | 29327.92 | 31006.49 | 11.54 |
| 660 | 35859.36 | 37911.75 | 14.11 |
| 730 | 43610.67 | 46106.71 | 17.16 |

**Table 6: CPG**

| Size | Free Inlet F | Ducted Inlet F | A |
|---|---|---|---|
| 121 | 944.92 | 996.36 | 0.344 |
| 141 | 1206.40 | 1272.08 | 0.439 |
| 161 | 1518.58 | 1601.26 | 0.552 |
| 181 | 1929.92 | 2035.00 | 0.702 |
| 201 | 2378.68 | 2508.19 | 0.865 |
| 221 | 2979.06 | 3141.26 | 1.083 |
| 251 | 3779.67 | 3985.45 | 1.375 |
| 281 | 4792.02 | 5052.92 | 1.743 |
| 321 | 6093.21 | 6424.95 | 2.216 |
| 351 | 7719.69 | 8139.98 | 2.807 |
| 391 | 9514.73 | 10032.75 | 3.460 |
| 441 | 11916.25 | 12565.02 | 4.334 |
| 491 | 14881.53 | 15691.74 | 5.412 |

**Table 7: AFE**

| Size | Free Inlet F | Ducted Inlet F | A |
|---|---|---|---|
| 122 | 872.75 | 894.27 | 0.325 |
| 150 | 1305.09 | 1337.28 | 0.486 |
| 165 | 1587.06 | 1626.20 | 0.591 |
| 182 | 1936.15 | 1983.91 | 0.721 |
| 200 | 2322.85 | 2380.14 | 0.865 |
| 222 | 2884.09 | 2955.23 | 1.074 |
| 245 | 3490.99 | 3577.10 | 1.300 |
| 270 | 4248.26 | 4353.05 | 1.582 |
| 300 | 5255.28 | 5384.90 | 1.957 |
| 330 | 6342.85 | 6499.31 | 2.362 |
| 365 | 7747.30 | 7938.40 | 2.885 |
| 402 | 9425.66 | 9658.16 | 3.510 |
| 445 | 11506.83 | 11790.66 | 4.285 |
| 490 | 13958.57 | 14302.88 | 5.198 |
| 542 | 17121.95 | 17544.28 | 6.376 |
| 600 | 20937.86 | 21454.32 | 7.797 |
| 660 | 25333.82 | 25958.71 | 9.434 |
| 730 | 30989.22 | 31753.60 | 11.54 |
| 807 | 37890.63 | 38825.25 | 14.11 |
| 890 | 46081.02 | 47217.66 | 17.16 |

**Table 8: MH Industrial**

| Size | Free Inlet F | Ducted Inlet F | A |
|---|---|---|---|
| 905 | 410.40 | 448.22 | 0.123 |
| 907 | 828.77 | 905.13 | 0.249 |
| 909 | 1392.65 | 1520.97 | 0.418 |
| 911 | 2102.04 | 2295.74 | 0.630 |
| 913 | 2956.96 | 3229.43 | 0.887 |
| 915 | 3957.39 | 4322.05 | 1.187 |
| 917 | 5103.34 | 5573.59 | 1.530 |
| 919 | 6394.80 | 6984.06 | 1.917 |
| 921 | 7831.78 | 8553.45 | 2.348 |
| 923 | 9311.11 | 10169.10 | 2.792 |
| 926 | 11944.07 | 13044.67 | 3.581 |
| 929 | 14904.43 | 16277.82 | 4.469 |
| 933 | 19360.90 | 21144.93 | 5.805 |
| 937 | 24399.43 | 26647.75 | 7.316 |
| 941 | 30020.04 | 32786.27 | 9.001 |
| 945 | 36222.71 | 39560.50 | 10.861 |
| 949 | 43007.45 | 46970.43 | 12.896 |
| 954 | 51820.34 | 56595.39 | 15.538 |
| 960 | 64125.64 | 70034.58 | 19.228 |

## Transducer Sizing for Piezometer Ring

Selecting a pressure transducer with the appropriate range is critical in order to get accurate measurements using the piezometer ring. Since most transducers list accuracy as a percent of full scale, if the range selected is too high, this can have a significant impact on the accuracy of the flow measurement. If the range is too low, there is risk of damaging the instrument and/or getting inaccurate readings or no reading at all.

The following steps are for sizing the pressure transducer for use with the piezometer ring flow measurement system:

1. Determine the maximum flow rate in CFM that the fan is expected to produce. This maximum should be the greater of normal, maximum, and/or emergency conditions.
2. Find the formula for calculating the actual flow rate from page 1 of this document for the corresponding size and type of fan being used.
3. Calculate the pressure drop corresponding to the maximum flow rate determined in Step 1.
4. Select the pressure transducer with the smallest range that includes the pressure drop calculated in Step 3.
5. Now take the maximum range from the pressure transducer selected in Step 4 and use that to calculate the maximum flow rate that could be measured with this transducer.
6. Determine an acceptable safety factor for sizing the transducer.
7. Multiply the maximum flow rate from Step 1 by the safety factor. If the maximum flow rate from Step 5 is less than the result, bump up the transducer to the next largest size. Otherwise, the transducer from Step 4 should be used.

**Example:**
Company XYZ has a size 270 CB SWSI fan to be installed with design conditions of 12,000 CFM at 5 inches w.g. and standard density. What size transducer should be used?

1. After speaking to the design engineer, it was determined that 12,000 CFM is the actual maximum and most of the time the fan will be running closer to 10,000 CFM. Therefore, 12,000 CFM will be used for the calculations.
2. The calculation for this fan type and size is:
   $ACFM = 4247.77 * \sqrt{(\Delta P)}$ for standard density
   Note that if the density was other than standard air, the formula would be different.
3. By rearranging the formula in Step 2, the following formula is obtained:
   $\Delta P = (ACFM/4247.77)^\wedge 2$
   so, $\Delta P = (12000/4247.77)^\wedge 2 = 7.98$ inches w.g.
4. For the pressure transducer models being considered, the ranges are 0-3, 0-6, 0-10, and 0-20. Therefore, for this flow rate the transducer model is the 0-10 inches w.g. model.
5. The maximum for this transducer is 10 inches, which corresponds to the following flow rate:
   $ACFM = 4247.77 * \sqrt{(10)} = 13433$ CFM
6. Since 12,000 CFM is the maximum and normal operating conditions are 10,000 CFM, a 10% safety factor should be plenty for this application
7. From Step 1, 12000 CFM * 1.1 = 13200 CFM. This is less than 13433 CFM, so the 0-10 inch pressure transducer is acceptable.

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