Air Balancing

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This document provides general information necessary to balance Titus HVAC equipment. Use this document along with the specific product flow factors to balance air distribution equipment.

Additional information may be found at the Titus website, its address is www.titus-hvac.com.

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Foreword

The intention of an air conditioning engineer is to design an air distribution system to deliver the required air volume to satisfy the space load. The duct system components are sized to deliver air without excessive balancing. Under ideal conditions, the pressure loss from the fan to the supply outlets should be sufficient to overcome the pressure loss through the supply outlet and distribute the air to the space. This ideal system would require no further airflow adjustments. However, in reality this condition is usually not met. Therefore, the system and component balancing is required to achieve the engineer's design criteria.

Introduction

When fans operate at a constant speed they have such characteristics that for a given air flow rate a certain pressure will be developed at the fan discharge. If the pressure requirement changes, the quantity of air delivered will also change. It is important to note that each downstream damper adjustment affects the fan pressure and airflow. An individual outlet cannot be adjusted without affecting the rest of the system. Therefore the system must be balanced in accordance with some systematic procedure. The objective of the manual is to provide a basic understanding of air conditioning system balancing. The balancing method presented within this manual uses a velometer positioned by hand at each grille. The method is generally referred to as the "Chicago Proportional Balancing" method.

Methodology

Figure 1 shows a typical example of a fan and duct system pressure characteristic. The duct system has four supply outlets with a damper in each outlet's branch line. There is also a damper in the main duct between the fan and the first branch takeoff. Each part of the system has the characteristic that the pressure required to overcome the resistance of that section of the system varies as the square of the volume of air flowing through it. Curve A shows the pressure characteristic of the last section of the duct from station 0 to 1, curve B represents the system including the last two supply outlets and so on. The following numerical examples illustrate the relationship between the volume of air flowing through a section of the system and the required pressure to overcome the resistance of that section.
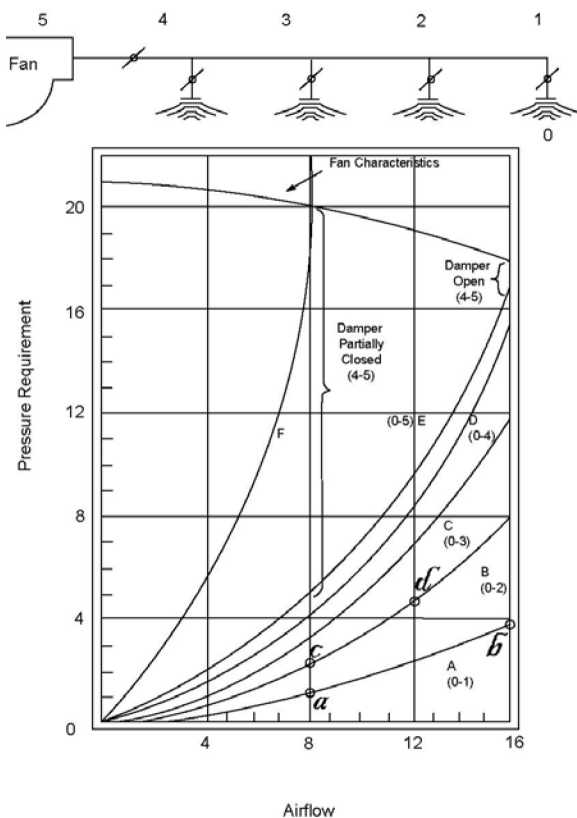

Figure 1. Fan and System Characteristics

FLOW AND PRESSURE REQUIREMENTS

The following are examples of flow and pressure requirements occurring in an air distribution system.

EXAMPLE – AIR VOLUME

At the "a" on the A curve; the required pressure is 1 for 8 units of air volume flow per unit time. When the flow is increased from 8 units at a "a" to 16 units at "b" then,

$$\frac{16 \text{ flow units}}{8 \text{ flow units}} = 2 \text{ and } (2)2 = 4$$

Therefore, the required pressure at point "b" is

$$1 \text{ pressure unit x } 4 = 4 \text{ pressure units}$$

EXAMPLE – AIR PRESSURE

At the "C" on the B curve, the required pressure is 2 for 8 units of airflow. When the flow is increased from 8 units at "c" to 12 units at "d" then,

$$\frac{12 \text{ flow units}}{8 \text{ flow units}} = 1.5 \text{ and } (1.5)2 = 2.25$$

Therefore, the required pressure at point "d" is

$$2 \text{ pressure units x } 2.25 = 4.5 \text{ pressure units}$$

Example – Fan Total Pressure

The following general equation may be used to perform fan pressure calculations.

$$\text{Fan Total Pressure}_2 = \text{Fan Total Pressure}_1 \text{ x } \left(\frac{\text{Vol. Flow}_2}{\text{Vol. Flow}_1} \right)$$

Therefore, based upon this basic fan law, a 20 percent increase in fan volume requires

$$(1 + 0.2)^2 = 1.44 \text{ or } 44\% \text{ higher fan total pressure}$$

EXAMPLE – FAN VOLUME

Another useful basic fan law is as follows:

$$\text{Fan Vol. Flow}_2 = \text{Fan Vol. Flow}_1 \text{ x } \frac{(\text{Fan RPM2})}{(\text{Fan RPM1})}$$

Such that a 10 percent increase in fan volume requires a 10 percent increase in fan speed.

Definitions

Anemometer

Instrument used for determining the force or speed of air. Two anemometer types are as follows:

- **Vane:** Used to measure sidewalls, grilles, registers, and ceiling diffusers. The vane anemometers are commonly depicted with balancing Titus air system equipment.

- **Rotating vane:** Used to measure linear feet of air passing through it. Generally used for measuring air velocity through supply, return and exhaust air grilles, registers, or openings. Do not use a rotating vane anemometer as an averaging instrument.

Area Factor

The area factor, A_K, is the effective area of the outlet at the point of outlet velocity, the V_K measurement is such that the volume flow is equal to A_K times V_K.

The area factors are based on equalized airflow 12 flow units in the outlet neck.

Note: Severe damper throttling or takeoffs without air turning devices or control grids can affect the indicated airflow accuracy of these factors dramatically.

Velocity

The measurement of air speed as it exits the grille, register, or diffuser. Velocity is averaged by number of readings taken at grille, register, or diffuser. Velocity is measured with instruments and depending on application, the velocity being measured can be either supply or return air.

Velometer

Instrument used for HVAC balancing, static pressure measurements, energy audits.

Instrumentation

We recommend all system balancing instruments calibrated annually with the manufacturer's furnished calibration curve. Also, it is strongly recommended these instruments be used within their specified accuracy range. The appropriate usage and accurate instrument calibration ensures ongoing credibility and accuracy for the air balancing technician.

For return grille balancing, the position of the velometer probe must be as shown in the diagrams for each diffuser shown. Based on the vane anemometer use, the attachment of the tubing to the anemometer requires a reversing movement on the instrument. Alternative methods may use a flow hood in a similar manner. Consult organizations such as NEBB and AADC for more information on those methods that use the flow hood to measure volume flow directly.

Preliminary Balancing Steps

Use the following information to balancing preparation.

1. Open all system air valves and dampers in both supply and return ducts.

2. Set all other dampers to normal operating position.

3. Check all filters and coils to ensure they are clear of dirt and debris.

4. Start all fans.

5. Check rotation of all fans and ensure the direction is correct.

6. Copy the balancing worksheet provided in this manual to record readings.

7. Number the outlets on the worksheet.

    Note: The furthest branch and the furthest outlet on the branch away from the fan will be outlet one on the branch number one. The outlets are numbered consecutively working back toward the fan. Figure 2 shows the numbering arrangement.

    It is very important the outlets be numbered, tested, and adjusted in the described sequence. If the sequence is not followed, the procedure will not be valid.

8. Spot-check outlets along the branch to determine if enough air is being delivered to give measurable readings.
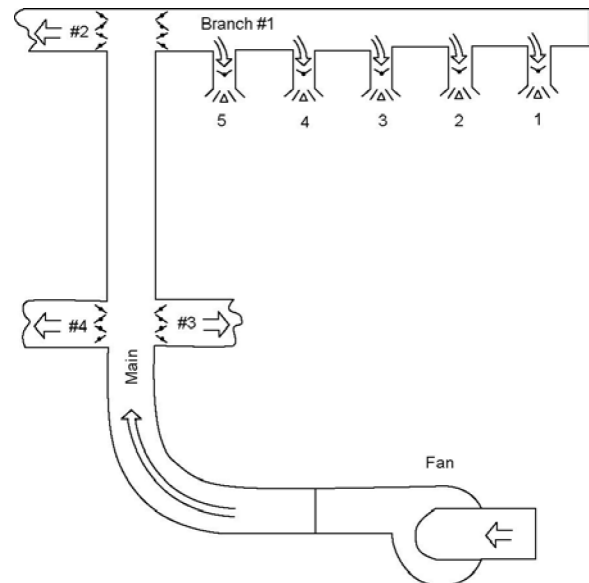

Figure 2. Schematic Diagram of the Duct System

Proportional Balancing Steps

The following balancing information is specific to low pressure ventilating and air conditioning systems.

1. Measure velocities at Outlet 1, the furthest outlet on the branch.

2. Determine the average velocity and use the System Balancing Worksheet to record the value in the column VM (measured velocity) under Adjustments I heading. This indicates the first reading of that outlet.

3. Determine the ratio of VD (measure to design velocity) and record R (ratio) under Adjustment I and 1B. Use the following equation to determine ratios.

$$R = \frac{\text{Measured Velocity VM}}{\text{AK (flow factor)}} = VD$$

4. Proceed to the second outlet. Determine the average velocity (VM) and ratio (R) and record these values under Adjustment I and 2A.

5. Compare R values from 1B and 2A under Adjustment I. If the R values are not equal, adjust Outlet 2 so R2 will approach R1. Do not adjust Outlet 1.

6. After adjustment, record VM and R values for Outlet 2 under II and 2A.

7. Go back to Outlet 1 and measure VM. Record VM and R values under Adjustment II, 1B. If R values shown under adjustment II, 1B and 2A vary more than 0.1, they are not proportionally balanced one to another and further adjustment to Outlet 2 is required. After each adjustment of outlet number, record the new VM and R values under 1B and 2A in each successive adjustment column. Once the prescribed limits are achieved, proceed to the next step.

8. After Outlets 1 and 2 are satisfactorily balanced one to another, the final adjustment values of R and VM from row 2A should be rewritten under column Adjustment I, row 2B.

9. Proceed to Outlet 3 and measure VM and record VM and R values under Adjustment I, 3A.

10. Compare 3A and 2B readings under Adjustment I. If necessary adjust Outlet 3 to achieve the same R values as shown for number 2.

    Note: Do not adjust Outlets 2 or 1.

    Any adjustments to Outlet 3 will change the flow through Outlets 2 and 1; however, as long as Outlet 2 or 1 are adjusted they will remain proportionally balanced to each other. The R value determined for Outlets 2 and 3 will also apply to Outlet 1 and they will be proportionally balanced to each other.

11. Adjust Outlet 4 so its R value matches Outlet 3's R value. Proceed in same manner to each outlet in the branch until out outlets are balanced proportionally to each other.

    It is essential that once an outlet is proportionally balanced with the preceding outlet, no further adjustments be made to that or a preceding outlet.

12. Balance each branch in a similar manner.

13. Measure airflow at a selected outlet in each of the two branches farthest from the fan. Adjust branch dampers until the R values for the selected outlets are equal. The two branch ducts are not proportionally balanced.

14. Adjust each branch to balance it proportionally with the preceding branch in the same manner that the outlets were balanced.

Grille Free Area

Grille free area (AF/AC) is the area free of obstruction in a grille face. The more free space, the more unobstructed airflow. The following table provides the average percentage of free grille area, deflection degree, and grille model number

Table 1. Grille Free Area (A_F/A_C)

Model	Deflection (Degrees)	Free Area (%)
3F	45	52%
4F	45	62%
23R	45	44%
25R	30	62%
30R	0	75%
33R	38	61%
50F	N/A	90%
111R & 112	0	88%
271 & 272	0	82%
	45	63%
	22.5	76%
300	see 271 & 272	
350	35	58%
355	35	46%
355 ZRL	0	80%
1700	N/A	68%
CT-480	N/A	47%
CT-481	N/A	42%
CT-540	N/A	56%
CT-541	N/A	51%
CT-580	N/A	69%
CT-581	N/A	65%
CT-700	N/A	56%
T-700	N/A	56%

Cross Reference

Table 2 provides a listing of products and their respective flow factor document.

Table 2. Product Cross Reference of Flow Factors

Product	See Flow Factor…	Product	See Flow Factor…
30	272-FF	CT-580	CT-FF
111	272-FF	CT-581	CT-FF
112	272-FF	CT-700	T700-FF
121	272-FF	CT-700 Core	272-FF
122	272-FF	DL	DL-FF
131	272-FF	FlowBar	FB-FF
132	272-FF	FR-1, -2, -3, -4	FR-FF
271	272-FF	LL-1	LL1-FF
272	272-FF	LL-2	LL2-FF
1700	1700-FF	ML-37	ML-FF
23 - Core	272-FF	ML-38	ML-FF
25 - Core	272-FF	ML-39	ML-FF
250 1-way	250-FF	N-1	N1-FF
250 2-way	250-FF	N-1-DR	N1DR-FF
250 3-way	250-FF	OMNI	OMNI-FF
250 4-way	250-FF F	PAR	PAR-F
3 - Core	272-FF	PAS	PAS-FF
30 - Core	272-FF	PDR	PAR-FF
300FL	272-FF	PDS	PAS-FF
300FS	272-FF	PFR	PFS-FF
300HD	300HD-FF	PFS	PFS-FF
300RL	272-FF	PSS	PSS-FF
300RS	272-FF	R-OMNI	R-OMNI-FF
301FL F	272-FF	SG-SD	SGSD-F
301FS	272-FF	T700	T700-F
301RL	272-FF	T700 - Core	272-FF
301RS	272-FF	TBD-10	TBD-10-F
33 - Core	272-FF	TBD-30	TBD-30-FF
34 - Core	272-FF	TBD-80	TBD-80-FF
350FL Core	272-FF	TBDI-10	TBD-10-F
350FS Core	272-FF	TBDI-30	TBD-30-FF
350RL Core	272-FF	TBDI-80	TBD-80-FF
350RS Core	272-FF	TDC	TDC-FF
355	272-FF	TBF	TBF-FF
4 - Core	272-FF	TLF	TLF-FF
50 - Core	272-FF	TMR	TMR-FF
50F	50-FF	TMRA	TMRA-FF
8 - Core	272-FF	TMR-AA	TMR-FF
CT-480	CT-FF	TMRA-AA	TMRA-FF
CT-481	CT-FF	TMS	TMS-FF
CT-540	CT-FF	TMSA	TMSA-FF
CT-541	CT-FF	XC-310	XC310-FF

System Balancing Worksheet

Outlet Product Information						Adjustments							
	Outlet		K-Factor	Design			I		II		III		iv
Outlet No.	Type	Size		CFM	V_D		V_M	R	V_M	R	V_M	R	V_M	R
1						1A								
						1B								
2						2A								
						2B								
3						3A								
						3B								
4						4A								
						4B								
5						5A								
						5B								
6						6A								
						6B								
7						7A								
						7B								
8						8A								
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9						9A								
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11						11A								
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12						12A								
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13						13A								
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14						14A								
						14B								
15						15A								
						15B								

Notes

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