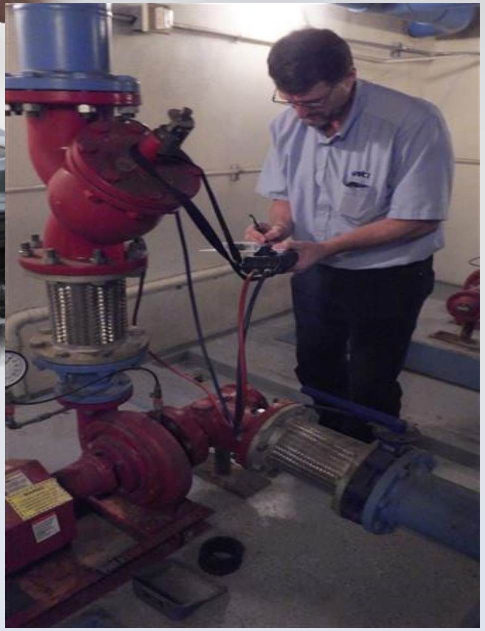
Quick Guide to Applying Fan & Pump Laws



Scott Fielder

Director, National Balancing Council

NCI National Comfort Institute, Inc.

AHR EXPO Atlanta JAN 14-16 · 2019

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Fan and Pump Laws

I had the great privilege of being raised in this industry, by a company that *demanded* all employees would learn to balance air and hydronic systems at the same time.

This same company also insisted that every field technicians learned our affinity laws and applied them. We learned our fan laws and pump laws as we learned to balance air and hydronic systems at the same time.

Fan and Pump Laws

One of the very first classes I ever taught with this organization, after over sixteen years in the field,

I was covering the Fan Laws, and a 25 year industry veteran with time in TAB, service, install, air and hydronics, boilers, steam, etc., incredibly knowledgeable and experienced professional and he stated…

“You may know the fan laws off of the top of your head because you teach these every day, but those of us in the field aren’t used to applying them every day.”

My Response was:

“This is only the second class I’ve taught. I know my Fan Laws because I USE them every day.”

Fan Laws & Pump Laws

To be very clear, this is not a presentation on Engineering and college level theory in regard to the affinity laws…

Fan Laws & Pump Laws

Nor is it Voodoo Magic to cut corners on TAB projects

Fan Laws & Pump Laws

The TAB professional must take multiple readings, with multiple, calibrated instruments and apply various formulas and calculations to ensure that the recorded readings make sense and are repeatable.

Fan Laws & Pump Laws

It’s not only critical for a TAB Professional to simply KNOW their fan & pump laws, but when and how to apply them as well.

QUICK TIP

There are multiple apps for fan and pump laws.

A couple of the free apps are

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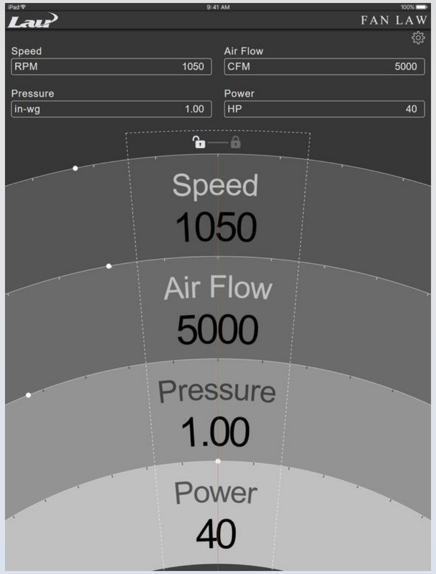

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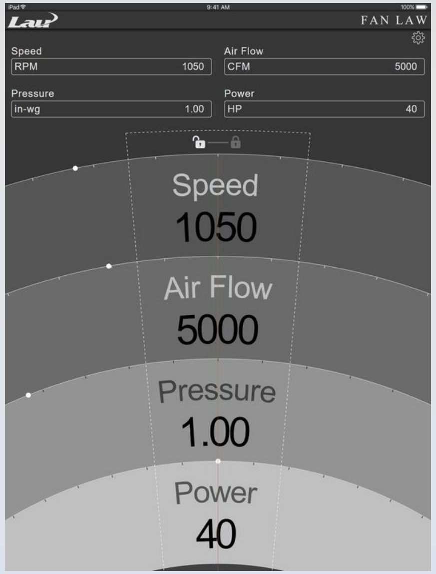

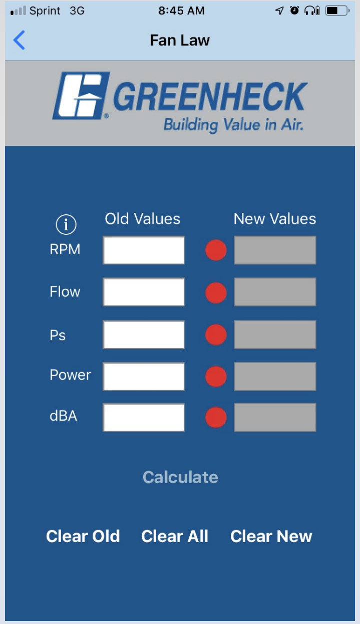

QUICK TIP

Apps have their time and place, however, like any tool,

They only work as well as the person using them.

And they are a lot more practical if the person using them is more familiar with their fan laws.

Fan Law Abbreviations

1. Subscript numbers (SP_2) represent the type of value measured
   - Subscript_1 is the current value you measured
   - Subscript_2 is the value you are solving for
2. PD = Pulley Diameter / Pitch Diameter
3. RPM = Revolutions Per Minute
4. SP = Static Pressure
5. AMP = Amperage (or Horsepower)
6. CFM = Cubic Feet Per Minute

Fan Law Abbreviations

NOTE:

PD = Pulley Diameter / Pitch Diameter

Pully Diameter (Sheave Diameter) refers to the OUTSIDE diameter of the Pully or Sheave.

Pitch Diameter is where the belt rides. They can be used interchangeably, but not on the same calculation.

Pitch Diameter is the more accurate of the two.

Pump Law Abbreviations

1. Subscript numbers (SP_2) represent the type of value measured
   - Subscript_1 is the current value you measured
   - Subscript_2 is the value you are solving for
2. ID = Impeller Diameter
3. RPM = Revolutions Per Minute
4. TDH = Total Dynamic Head
5. BHP = Brake Horse Power
6. GPM = Gallons Per Minute

Fan Laws

After completing the initial measurements of fan performance, you can use fan laws to determine

1. How much to change the adjustable pulley diameter
2. What the new airflow will be
3. What the new fan rpm will be
4. What the static pressure will increase or decrease to
5. What the new fan motor amperage will be
6. Where to set the SP Set point on a BAS / EMS

$$PD_2 = PD_1 \times \left(\frac{CFM_2}{CFM_1} \right)$$

Pump Laws

After completing the initial measurements of fan performance, you can use fan laws to determine

1. How much to change the impeller size
2. What the new hydronic flow will be
3. What the new pump rpm will be
4. What the head pressure will increase or decrease to
5. What the new pump motor amperage / BHP will be
6. Where to set the DP Setpoint on a BAS / EMS

Parentheses

In a mathematic formula (Parentheses) mean “Do this part of the formula first”. So in most fan laws, The CFM_2 (the new CFM) divided by CFM_1 (current CFM) is the first step in the formula.

Squared^2 or Cubed^3

Fan Law Two requires the ratio of CFM_2 and CFM_1 be squared (multiply a number by itself). For example 4^2 equals 4 x 4 or 16.

Fan Law Three requires the CFM ratio to be cubed (multiply a number by itself twice). For example 4^3 equals 4 x 4 x 4 or 64.

Bottom Line Math

When calculating Fan / Pump Law One, divide once, and multiply once.

When calculating Fan / Pump Law Two and Three, there is one added step. Just after dividing, square or cube the CFM ratio.

QUICK TIP – Fan Law / Pump Law 2

When training your staff and technicians, remember –

Static Pressure - SP

Differential Pressure – DP

Delta P –▲P

$$SP_2 = SP_1 \times \left(\frac{CFM_2}{CFM_1} \right)^2$$

All have TWO letters, so they are SQUARED or SQUARE ROOTED

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QUICK TIP – Fan Law / Pump Law 2

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QUICK TIP – Fan Law / Pump Law 3

When training your staff and technicians, remember –

Amperage - AMP

Break Horse Power - BHP

$$AMP_2 = AMP_1 \times \left(\frac{CFM_2}{CFM_1} \right)^3$$

All have THREE letters, so the are CUBED OR CUBE ROOTED

QUICK TIP – Fan Law / Pump Law 3

When training your staff and technicians, remember –

Amperage - AMP

Break Horse Power - BHP

$$AMP_2 = AMP_1 \times \left(\frac{CFM_2}{CFM_1} \right)^3$$

All have THREE letters, so the are CUBED or CUBE ROOTED

Fan Law Introduction

Fan Law One calculates the change in pulley diameter needed in order for the fan to deliver the required cfm. A version of it will also calculate the change in the fan rpm.

Airflow changes at the same rate as fan rpm and pulley diameter change. If the pulley diameter increases 10%, airflow and fan rpm also increase 10%.

$$PD_2 = PD_1 \times \left(\frac{CFM_2}{CFM_1} \right)$$

Fan Law Two[2]

calculates how static pressure changes as airflow changes. It calculates change in total external static pressure and change in pressure drop through system components.

Pressure changes at the square of airflow. So if airflow increases 10%, total external static pressure increases 21%. Pressure increases at more than twice the rate of airflow.

$$SP_2 = SP_1 \times \left(\frac{CFM_2}{CFM_1} \right)^2$$

Fan Law Three[3]

calculates how fan motor amperage or horsepower changes as airflow changes.

Amperage changes at the cube of airflow. If airflow increases 10%, the amp draw of the blower motor increases 33%. Amperage increases at more than three times the rate of airflow.

$$AMP_2 = AMP_1 \times \left(\frac{CFM_2}{CFM_1} \right)^3$$

Using Fan Law One

To recalculate the required pulley size for the fan or to calculate the fan rpm needed to deliver the correct airflow, use Fan Law One.

Example:

We have a 5.5" adjustable motor pulley, the fan is currently delivering 5100 cfm, and the 15 ton system requires 6000 cfm

$$PD_2 = PD_1 \times \left(\frac{CFM_2}{CFM_1} \right)$$

$$PD_2 = 5.5'' \times \left(\frac{6{,}000\ CFM}{5{,}100\ CFM} \right)$$

$$6.49'' = 5.5'' \times 1.18$$

Adjust motor pulley to 6.49" (6.5") to take airflow to 6000 cfm.

QUICK TIP – Fan Law 1

Please DO NOT tell the owner or contractor to purchase a 6.49" Motor Pulley! Or worse yet, something like 6.4562" Pulley.

Select a model number from a catalog and state "or equivalent". Provide the owner or contractor with an option they can actually purchase.

Also be certain to get the bore side correct and double check your belt calculation.

Fan Law Two

Calculates changes in static pressure and is used to calculate new total external static pressure after airflow is increased.

Example:

The 15 ton system total external static pressure is 1.22” with airflow at 5100 cfm and fan rated at 2.0”. What will the new static pressure be when we adjust the motor pulley to 6.5” and airflow increases to 6000 cfm?

$$SP_2 = SP_1 \times \left(\frac{CFM_2}{CFM_1} \right)^2$$

$$SP_2 = 1.22'' \times \left(\frac{6{,}000\ CFM}{5{,}100\ CFM} \right)^2 \quad \text{Or} \quad \frac{6000}{5100} = 1.18$$

$$SP_2 = 1.22'' \times 1.18^2$$

$$1.70'' = 1.22'' \times 1.39$$

Example

What will the amp draw on this motor be at 6000 cfm?

$$AMP_2 = AMP_1 \times \left(\frac{CFM_2}{CFM_1} \right)^3$$

$$AMP_2 = 12.6\,AMP \times \left(\frac{6{,}000CFM}{5{,}100CFM} \right)^3 \quad \text{Or} \quad \frac{6000}{5100} = 1.18$$

$$AMP_2 = 12.6\,AMP \times 1.18^3$$

$$20.6\,AMP = 12.6\,AMP \times 1.64$$

PULLEY CALCULATIONS

DATE
August 14, 2017

PULLEY CALCULATIONS

19.5" CENTER DISTANCE

FAN PULLEY 7.25"

MOTOR PULLEY 4.75"

Test	Supply CFM	Fan RPM	Total Static Pressure	Amp Draw	Motor Pulley Diameter	Ratio
Test 1	3540	822	1.26"	6.2	3.8"	1.13
Test 2						

Fan Law One Pulley Size

$$PD2 = PD1 \times \left(\frac{CFM2}{CFM1}\right)$$

$$PD\,2 = 3.8 \times \left(\frac{4000}{3540}\right)$$

$$4.3" = 3.8" \times 1.13$$

Fan Law One RPM

$$RPM\,2 = RPM\,1 \times \left(\frac{CFM\,2}{CFM\,1}\right)$$

$$RPM\,2 = 822 \times \left(\frac{4000}{3540}\right)$$

$$929\,RPM = 822\,RPM \times 1.13$$

Fan Law Two Pressure

$$SP2 = SP1 \times \left(\frac{CFM\,2}{CFM\,1}\right)^2$$

$$SP2 = 1.26" \times \left(\frac{4000}{3540}\right)^2$$

$$SP2 = 1.26" \times 1.13^2$$

$$1.61" = 1.26" \times 1.28$$

Fan Law Three Amp Draw

$$AMP2 = AMP1 \times \left(\frac{CFM2}{CFM1}\right)^3$$

$$AMP\,2 = 6.2 \times \left(\frac{4000}{3540}\right)^3$$

$$AMP\,2 = 6.2 \times 1.13^3$$

$$8.9\,AMPS = 6.2 \times 1.44$$

Pulley Calculations

MOTOR NAMEPLATE DATA

MANUFACTURER	Marathon
VOLTS/PHASE	240/3
HORSEPOWER	3
FULL LOAD AMPS	11.4
RPM	1725
SERVICE FACTOR	1.15
MOTOR FRAME DATA	

BELT DATA

MANUFACTURER	N/A
MODEL	N/A
BELT SIZE	N/A

FAN	DESIGN	ACTUAL
SUPPLY AIR CFM	6000	5100
STATIC PRESSURE +		.37"
STATIC PRESSURE -		.71"
TOTAL STATIC PRESSURE	1.5"	1.08"
FAN RPM		855
MOTOR		
AMPS	11.4	8.6
VOLTS	240	238
HORSEPOWER	3	3

FORMULAS

FAN LAW ONE - PULLEY SIZE

$$PD2 = PD1 \times \left(\frac{CFM2}{CFM1}\right)$$

3.25 x 1.18 = 3.83

FAN LAW TWO - STATIC PRESSURE

$$SP2 = SP1 \times \left(\frac{CFM\,2}{CFM\,1}\right)^2$$

1.08 x 1.39 = 1.50

FAN LAW THREE - AMP DRAW

$$AMP2 = AMP1 \times \left(\frac{CFM2}{CFM1}\right)^3$$

8.6 x 1.64 = 14.1

FAN LAW ONE - RPM

$$RPM\,2 = RPM\,1 \times \left(\frac{CFM\,2}{CFM\,1}\right)$$

855 X 1.18 = 1009

FAN LAW THREE - AMP DRAW

$$AMP2 = AMP1 \times \left(\frac{CFM2}{CFM1}\right)^3$$

FAN LAW ONE - RPM

$$RPM\,2 = RPM\,1 \times \left(\frac{CFM\,2}{CFM\,1}\right)$$

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In that last example, we see that the motor will over amp at design flow.

It's very common to see remarks such as:

"Motor will over-amp at design flow. Need Larger motor."

However before that point, the TAB Contractor has the responsibility to tell the owner and design team what the most flow they can achieve the motor they currently have.

Based on your calculations in the previous exercise, what is the most cfm we can obtain at FLA? What are the static pressures, fan rpm and pulley size needed to achieve this?

$$5000 \text{ x } \left(\sqrt[3]{\frac{11.4}{8.6}}\right)$$

5610 CFM = 5000 x 1.10

$$SP_2 = .1.08'' \times \left(\frac{5610\ CFM}{5000\ CFM}\right)^2$$

Or $\frac{5610}{5000}$ = 1.12

$$SP_2 = .1.08'' \times 1.12^2$$

$$1.35'' = 1.08'' \times 1.25$$

1.35”

Based on your calculations in the previous exercise, what is the most cfm we can obtain at FLA? What are the static pressures, fan rpm and pulley size needed to achieve this?

$$RPM_2 = 855 \times \left(\frac{5610\,CFM}{5000\,CFM} \right)$$

$$958 = 855 \times 1.12$$

958 RPM

$$3.25 \text{ x } \left(\sqrt[3]{\frac{11.4}{8.6}} \right)$$

3.58” = 3.25 x 1.10

Fan laws teach the relationship between each of the measurements and show how they change together in a predictable fashion. Where airflow, pulley size and fan rpm will change at 10%, pressure will change at the square or at 21%. Motor Amp draw will change at the cube of airflow. If airflow changes 10%, motor Amp draw will change 33%.

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Caution!

When it comes to the accuracy of fan law calculations, understand that there are limits!

Fan / Pump Law 1

Fan Law One pulley size and rpm calculations are limited by the actual capacity of the fan or pump. You may calculate an rpm that exceeds the physical characteristics of the fan and the fan may not function as desired under that condition.

An example would be to exceed the tip speed and blow the fan apart.

Fan / Pump Law 2

Fan Law Two is accurate up to an increase in airflow of about 33%. Above that, the squared function of the calculation may cause inaccuracies.

Fan / Pump Law 3

Fan Law Three is accurate up to an increase in airflow of about 25%. Above that, the cubed function of the calculation may cause inaccuracies.

Using Fan Laws to Establish Set Points on Variable Flow Systems

Using Fan Laws to Establish Set Points on Variable Flow Systems

An example is if a terminal unit such as a Variable Air Volume box, or an actuator for a hydronic coil was 100% open but design flow parameters are not being achieved.

The fan and pump laws can be applied to tell the control contractor or facilities manager EXACTLY where to set the Static Pressure Set Point or the Differential Pressures Set Point on the Building Automation / Energy Management System.

Using Fan Laws to Establish Set Points on Variable Flow Systems

For instance ½” actuator is 100% open. The design flow is 2.5 GPM, but only 1.9 GPM is read. The current DP Set point is 7.5 PSI and the pump is operating at 40Hz.

We apply the following formula:

$$TDH_2 = TDH_1 \times \left(\frac{GPM_2}{GPM_1}\right)^2$$

Using Fan Laws to Establish Set Points on Variable Flow Systems

For instance ½” actuator is 100% open. The design flow is 2.5 GPM, but only 1.9 GPM is read. The current DP Set point is 7.5 PSI and the pump is operating at 40Hz.

$$DP_2 = 7.5 \times \left(\frac{2.5}{1.9}\right)^2$$

Using Fan Laws to Establish Set Points on Variable Flow Systems

For instance ½" actuator is 100% open. The design flow is 2.5 GPM, but only 1.9 GPM is read. The current DP Set point is 7.5 PSI and the pump is operating at 40Hz.

$$DP_2 = 7.5 \times \left(\frac{2.5}{1.9}\right)^2$$

$$DP_2 = 7.5 \times (1.32)^2$$

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Using Fan Laws to Establish Set Points on Variable Flow Systems

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$$DP_2 = 7.5 \times \left(\frac{2.5}{1.9}\right)^2$$

$$DP_2 = 7.5 \times (1.32)^2$$

$$DP_2 = 7.5 \times (1.73)$$

Using Fan Laws to Establish Set Points on Variable Flow Systems

For instance ½" actuator is 100% open. The design flow is 2.5 GPM, but only 1.9 GPM is read. The current DP Set point is 7.5 PSI and the pump is operating at 40Hz.

$$DP_2 = 7.5 \times \left(\frac{2.5}{1.9}\right)^2$$

$$DP_2 = 7.5 \times (1.32)^2$$

$$DP_2 = 7.5 \times (1.73)$$

$$DP_2 = 13\ PSI$$

Pump Law Two Variation

$$TDH_2 = TDH_1 \times \left(\frac{GPM_2}{GPM_1}\right)^2$$

Determining Coil Flow

The most common method of determining coil flow is by taking a pressure drop across the coil, between the entering and leaving sides of the coil, consistent with the second affinity law or pump law. Pressure increases at a square rate, or 2:1 ratio of fluid flow

Pump Law Two Variation

$$GPM_2 = GPM_1 \times \sqrt{\frac{TDH_2}{TDH_1}}$$

This is the formula used to convert pressure drop to GPM.

It's better expressed as….

Pump Law Two Variation

$$GPM_2 = GPM_1 \times \sqrt{\frac{PD_2}{PD_1}}$$

Pump Law Two Variation

This is the most practical expression of this formula when deriving GPM from coil pressure drop.

$$GPM_A = GPM_D \times \sqrt{\frac{\Delta P_A}{\Delta P_D}}$$

Pump Law Two Variation

$$GPM_A = GPM_D \times \sqrt{\frac{\Delta P_A}{\Delta P_D}}$$

Where:

GPM_A = Actual GPM

GPM_D = Design GPM

ΔP_A = Actual Pressure Drop

ΔP_D = Design Pressure Drop

QUICK TIP

When trying to remember which value to place on top and bottom, it's as simple as if the coil pressure drop is LESS THAN the design pressure drop,

The actual hydronic flow calculated MUST be less than the design hydronic flow. If it's not, the values are reversed.

Coil Flow "Cheat" With Fan Law Calculator

Chilled Water		5WC - 6 - 60 x 72 x 8 - 12 AL
Individual Coil Construction	**Entering Conditions**	**Leaving Conditions**
(Qty) FH x FL : (4) 60.00 x 72.00	ACFM : 60,000	Total Heat : 4,378,147 Btu/Hr
Rows - FPI : 8 - 12	SCFM : 60,000	Sensible Heat : 2,460,419 Btu/Hr
Serpentine : 1.333	Altd : 0 ft	
Total Face Area : 120.0 sq.ft	EDB : 90.0°F	LDB : 52.2°F
Fin Thick / Mat. : 0.008" / AL	EWB : 74.0°F	LWB : 51.9°F
Tube O.D. / Wall : 5/8" / 0.025"		
Tube Material : CU	EWT : 44.0°F	LWT : 59.1°F
Case Material : Stainless	Fluid : Water	FV : 500.0 ft/min
Conn Location : Same End	GPM : 580.00	APD : 1.64 in.WG
Sup.Conn - Qty / Size : (1) 3"		Water Velocity : 3.09 ft/s
Ret.Conn - Qty / Size : (1) 3"		Water PD : 8.71 ft

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Coil Flow "Cheat" With Fan Law Calculator

Step One: Find Design GPM

Chilled Water		5WC - 6 - 60 x 72 x 8 - 12 AL
Individual Coil Construction	**Entering Conditions**	**Leaving Conditions**
(Qty) FH x FL : (4) 60.00 x 72.00	ACFM : 60,000	Total Heat : 4,378,147 Btu/Hr
Rows - FPI : 8 - 12	SCFM : 60,000	Sensible Heat : 2,460,419 Btu/Hr
Serpentine : 1.333	Altd : 0 ft	
Total Face Area : 120.0 sq.ft	EDB : 90.0°F	LDB : 52.2°F
Fin Thick / Mat. : 0.008" / AL	EWB : 74.0°F	LWB : 51.9°F
Tube O.D. / Wall : 5/8" / 0.025"		
Tube Material : CU	EWT : 44.0°F	LWT : 59.1°F
Case Material : Stainless	Fluid : Water	FV : 500.0 ft/min
Conn Location : Same End	GPM : 580.00	APD : 1.64 in.WG
Sup.Conn - Qty / Size : (1) 3"		Water Velocity : 3.09 ft/s
Ret.Conn - Qty / Size : (1) 3"		Water PD : 8.71 ft
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Coil Flow "Cheat" With Fan Law Calculator

Step Two: Find Design Hydronic Pressure Drop

Chilled Water		5WC - 6 - 60 x 72 x 8 - 12 AL
Individual Coil Construction	**Entering Conditions**	**Leaving Conditions**
(Qty) FH x FL : (4) 60.00 x 72.00	ACFM : 60,000	Total Heat : 4,378,147 Btu/Hr
Rows - FPI : 8 - 12	SCFM : 60,000	Sensible Heat : 2,460,419 Btu/Hr
Serpentine : 1.333	Altd : 0 ft	
Total Face Area : 120.0 sq.ft	EDB : 90.0°F	LDB : 52.2°F
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Sup.Conn - Qty / Size : (1) 3"		Water Velocity : 3.09 ft/s
Ret.Conn - Qty / Size : (1) 3"		Water PD : 8.71 ft
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Coil Flow "Cheat" With Fan Law Calculator

Step Three: Read Actual Pressure Drop

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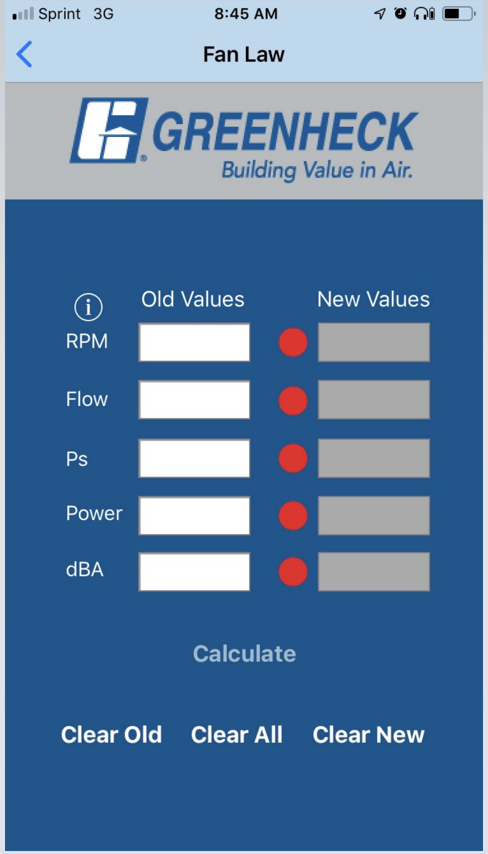
Coil Flow "Cheat" With Fan Law Calculator

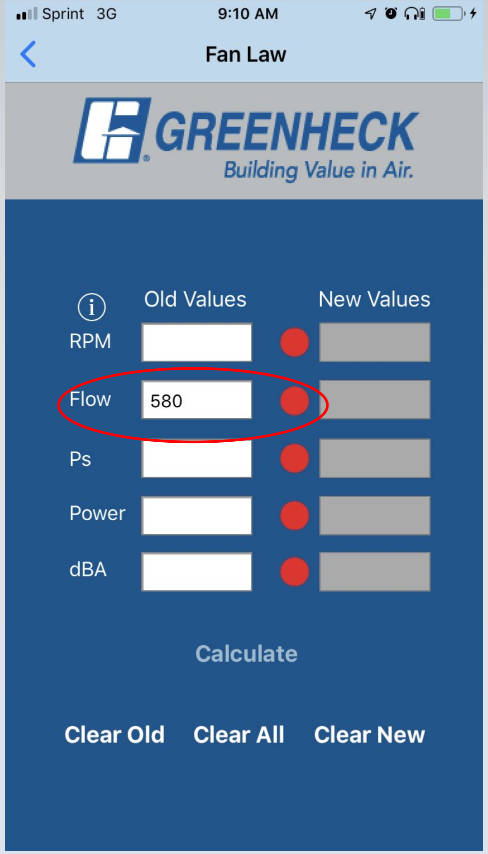
Step Four: Enter values into App



Coil Flow "Cheat" With Fan Law Calculator

Step Four: Enter values into App

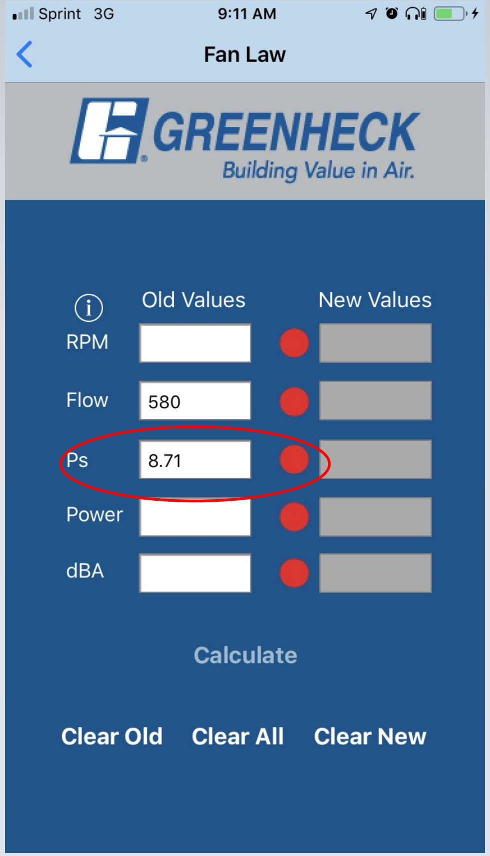
Design Flow



Coil Flow "Cheat" With Fan Law Calculator

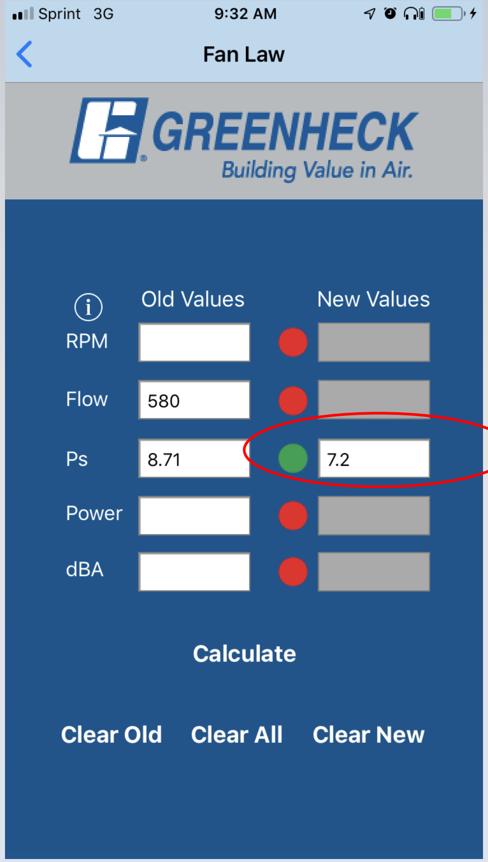
Step Four: Enter values into App

Design Pressure Drop



Coil Flow "Cheat" With Fan Law Calculator

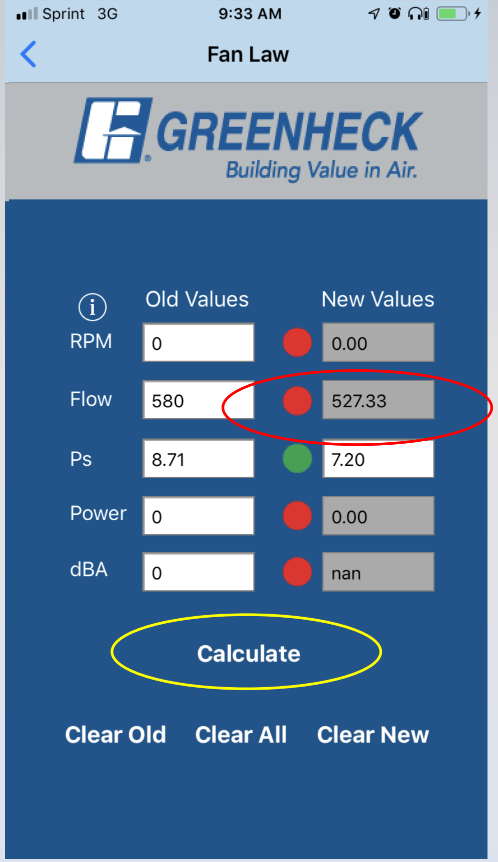
Step Four: Enter values into App



Actual Pressure Drop

Coil Flow "Cheat" With Fan Law Calculator

Step Five: Press Calculate

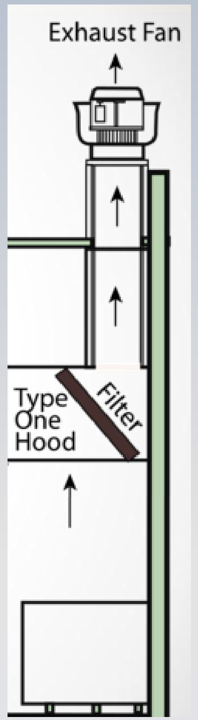


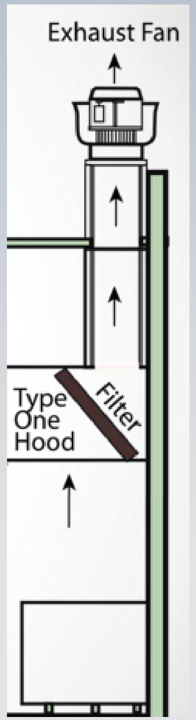
Actual Flow

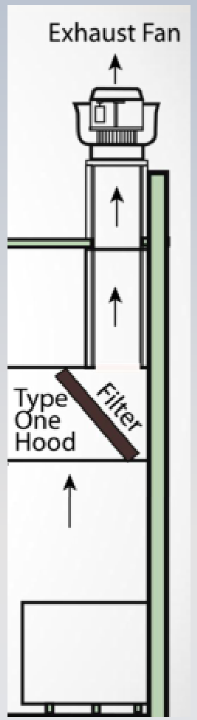
Kitchen Hood / Fan Laws Lesson

When teaching fan laws, I promise the students that I'll keep pointing out other methods to apply fan laws. This is an example I use during the Kitchen Hood Portion that was an actual tech support / admin support call when I was still in Texas working for NCI.

Then they had off-brand high extraction grease filters from a company that had gone out of business, so there was no useable data. So the TAB professional came up with the best method to read the airflow, remarked it and submitted the reports.



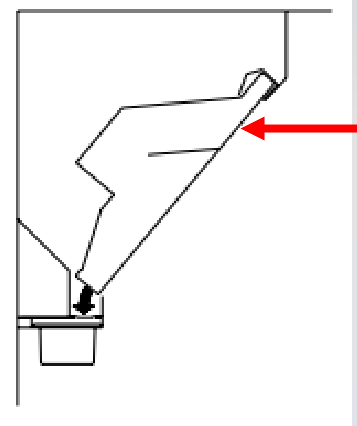




3 Identical Kitchen Hoods, ductwork & Exhaust Fans

Off-Brand Grease Baffle

- With no written manufacture's guidelines, The certified TAB professional used a calibrated, rotating vane anemometer and determined that since the instrument fit perfectly with the inlet of the grease baffle, he could simply use the open area. His airflow readings were consistent with design, as were his amps, TESP & Fan RPMs.
- The TAB professional then documented his method in the TAB report.



4" Opening

4" RVA

Off-Brand Grease Baffle

- With no written manufacture’s guidelines, The certified TAB professional used a calibrated, rotating vane anemometer and determined that since the instrument fit perfectly with the inlet of the grease baffle, he could simply use the open area. **His airflow readings were consistent with design, as were his amps, TESP & Fan RPMs.**
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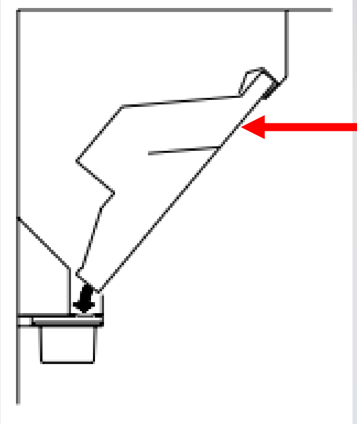
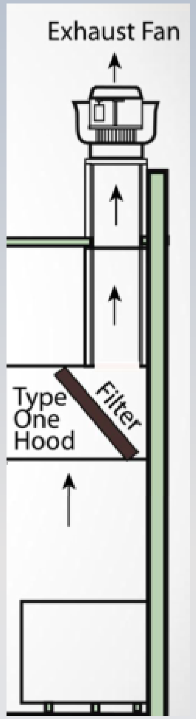


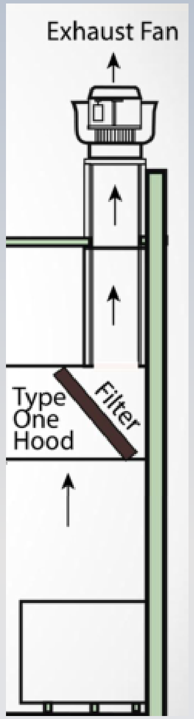
4” Opening

4” RVA

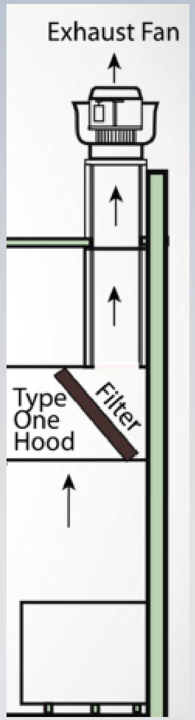
4.1 Amps
1025 Fan RPM
1.28 TESP



4.3 Amps
1069 Fan RPM
1.35 TESP



3.7 Amps
1001 Fan RPM
1.23 TESP



3050 CFM

3125 CFM

2980 CFM

Initial TAB Readings

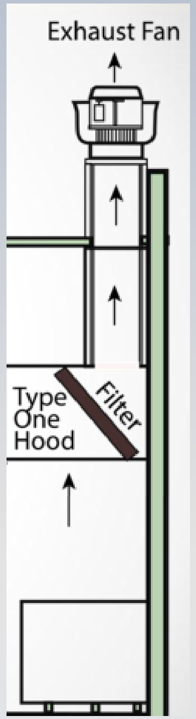
MEP Response

The design team reviewed the data, but didn't like the methodology used.

The design team called to have the "Manufacture's Rep" go verify the readings. (Remember, the new owner / distributor of the product line had already informed the TAB Professional that they weren't making it, just selling existing inventory and had no product experts on staff.)

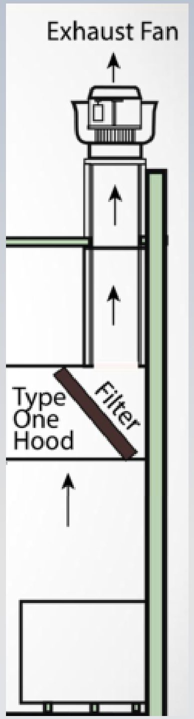
The "Manufacture's Rep" provided the data on the following page.

4.2 Amps
1030 Fan RPM
1.28 TESP



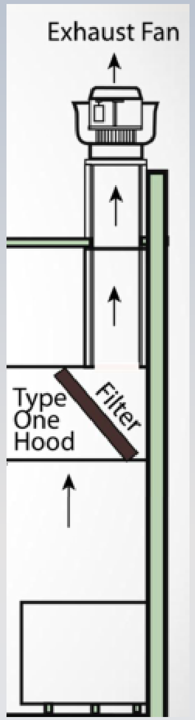
3890 CFM

4.4 Amps
1079 Fan RPM
1.31 TESP



2450 CFM

3.8 Amps
1011 Fan RPM
1.26 TESP

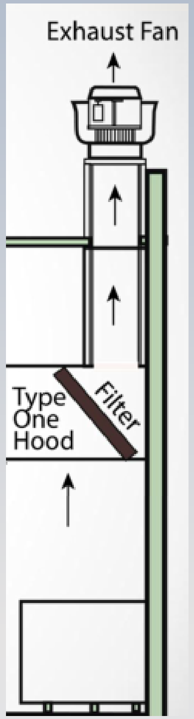


3425 CFM

“Manufacture’s” Readings

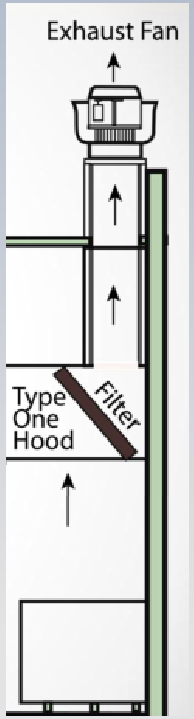
TAB
DATA

"Manufacture"
Data



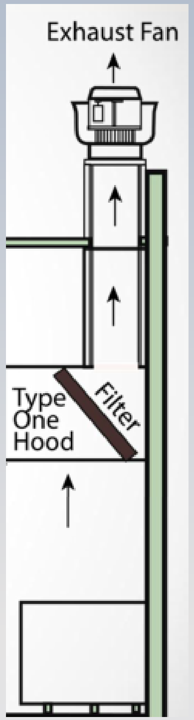
4.1 Amps
1025 Fan RPM
1.28 TESP

4.2 Amps
1030 Fan RPM
1.28 TESP



4.3Amps
1069 Fan RPM
1.35 TESP

4.2Amps
1079 Fan RPM
1.31 TESP



3.7 Amps
1001 Fan RPM
1.23 TESP

3.8 Amps
1011 Fan RPM
1.26 TESP

TAB DATA	3050 CFM	3125 CFM	2980 CFM
"Manufacture" Data	3890 CFM	2450 CFM	3125 CFM

Combined Readings

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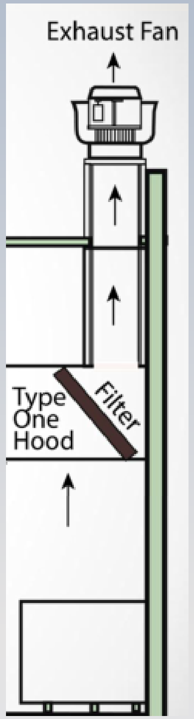
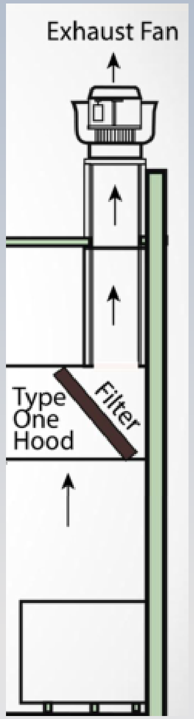
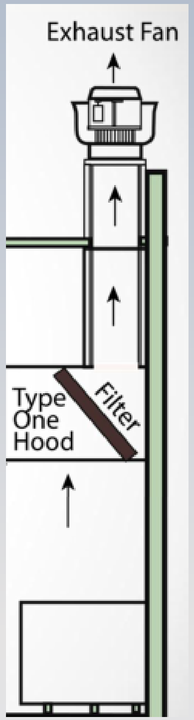
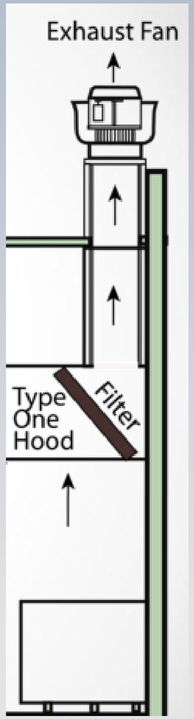
What Do our Fan Laws Tell Us About this situation?

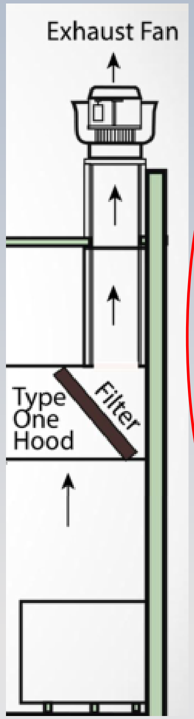


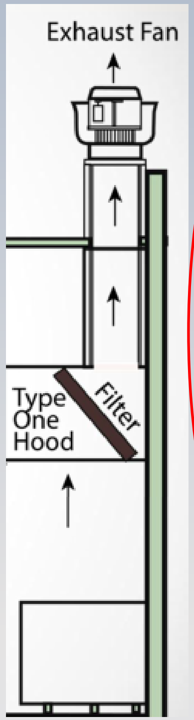




NCI / NBC DATA	4.1 Amps 1025 Fan RPM 1.28 TESP	4.3 Amps 1069 Fan RPM 1.35 TESP	3.7 Amps 1001 Fan RPM 1.22 TESP
"Manufacture" Data	4.2 Amps 1030 Fan RPM 1.28 TESP	4.2Amps 1079 Fan RPM 1.31 TESP	3.8 Amps 1011 Fan RPM 1.26 TESP
TAB DATA	3050 CFM	3125 CFM	2980 CFM
"Manufacture" Data	3650 CFM	2750 CFM	3125 CFM







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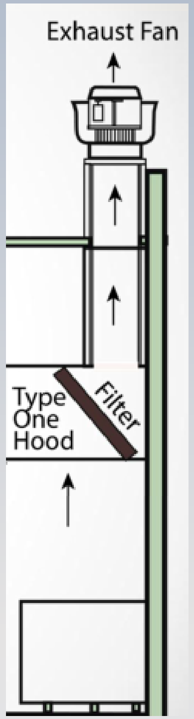
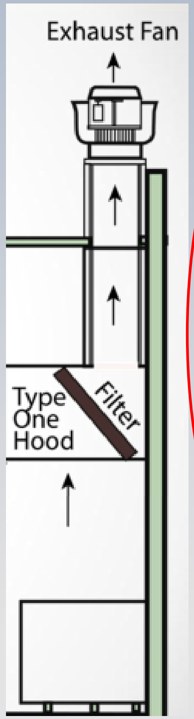
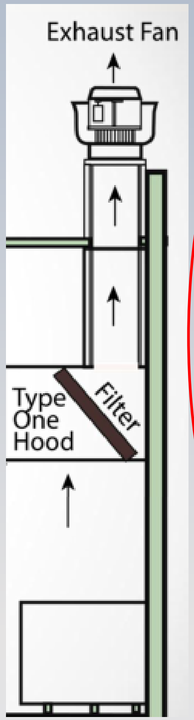
TAB DATA	3050 CFM	3125 CFM	2980 CFM
“Manufacture” Data	3650 CFM	2750 CFM	3125 CFM

Our FAN LAWS tell us that the airflow is the same. This is fire-rated, 16 gauge duct that was already proven to have zero leakage. Two different technicians produced almost IDENTICLE amps, fan rpms and TESP. Even if the TAB professional's readings are INNCORRECT, the "Manufacture's Readings" are **impossible**, as our FAN LAWS dictate that the air flow readings should be consistent. What do you think the "Manufacture's Rep" may have done wrong?







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TAB DATA	3050 CFM	3125 CFM	2980 CFM
"Manufacture" Data	3650 CFM	2750 CFM	3125 CFM

What Else Our Fan Laws Tell Us About this Situation

1) Whoever took the readings was not malicious. They were capable at reading AMPS, RPMs, and TESP. The fact they knew how to do this and matched the certified professional tells me they have done this before.

What Else Our Fan Laws Tell Us About this Situation

2) Whatever instrument they used, wasn't being used correctly. They were either twisting it or holding it a varying distances. It could also mean they used a cheap, uncalibrated instrument or a combination of both.

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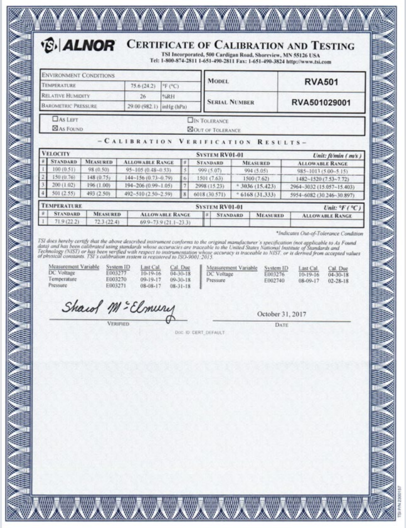
What Else Our Fan Laws Tell Us About this Situation

3) The Rep did not understand airflow or their fan laws. If they had, they would have recognized the fact that their airflow readings were not physically possible.

Engineer Meeting On Job Site To Confirm Data

The Certified TAB professional shows up first. He broke out his calibrated RVA, and even handed the MEP the actual calibration certificate to review. A little over kill, but he was taking nothing to chance.



TSI | ALNOR **CERTIFICATE OF CALIBRATION AND TESTING**

TSI Incorporated, 500 Cardigan Road, Shoreview, MN 55126 USA
Tel: 1-800-874-2811 1-651-490-2811 Fax: 1-651-490-3824 http://www.tsi.com

Environment Conditions		
Temperature	75.6 (24.2)	°F (°C)
Relative Humidity	26	%RH
Barometric Pressure	29.00 (982.1)	inHg (hPa)

Model	RVA501
Serial Number	RVA501029001

☐ As Left ☒ As Found ☐ In Tolerance ☒ Out of Tolerance

– CALIBRATION VERIFICATION RESULTS –

Velocity — System RV01-01 — Unit: ft/min (m/s)

#	Standard	Measured	Allowable Range	#	Standard	Measured	Allowable Range
1	100 (0.51)	98 (0.50)	95~105 (0.48~0.53)	5	999 (5.07)	994 (5.05)	985~1013 (5.00~5.15)
2	150 (0.76)	148 (0.75)	144~156 (0.73~0.79)	6	1501 (7.63)	1500 (7.62)	1482~1520 (7.53~7.72)
3	200 (1.02)	196 (1.00)	194~206 (0.99~1.05)	7	2998 (15.23)	* 3036 (15.423)	2964~3032 (15.057~15.403)
4	501 (2.55)	493 (2.50)	492~510 (2.50~2.59)	8	6018 (30.571)	* 6168 (31.333)	5954~6082 (30.246~30.897)

Temperature — System RV01-01 — Unit: °F (°C)

#	Standard	Measured	Allowable Range	#	Standard	Measured	Allowable Range
1	71.9 (22.2)	72.3 (22.4)	69.9~73.9 (21.1~23.3)				

*Indicates Out-of-Tolerance Condition

TSI does hereby certify that the above described instrument conforms to the original manufacturer's specification (not applicable to As Found data) and has been calibrated using standards whose accuracies are traceable to the United States National Institute of Standards and Technology (NIST) or has been verified with respect to instrumentation whose accuracy is traceable to NIST, or is derived from accepted values of physical constants. TSI's calibration system is registered to ISO-9001:2015.

Measurement Variable	System ID	Last Cal.	Cal. Due
DC Voltage	E003277	10-19-16	04-30-18
Temperature	E003270	09-19-17	09-30-18
Pressure	E003271	08-08-17	08-31-18

Measurement Variable	System ID	Last Cal.	Cal. Due
DC Voltage	E003276	10-19-16	04-30-18
Pressure	E002740	08-09-17	02-28-18

Sharol McElmury
Verified

October 31, 2017
Date

Doc ID: CERT_DEFAULT

The TAB Professional walked the engineer through what he did, how he did it, why he did it and produced the following readings compared to his original report:

Engineer Meeting On Job Site To Confirm Data

We live and work in a +/- 10% world. You will NEVER obtain the exact same readings twice. We balance fluids. They shift and move.

However, if we do things properly, we should ALWAYS be able to repeat our recorded values within +/- 5%, 10%. If it exceeds that ratio, you or your technician didn't do it correctly, or you are not maintaining your instruments.

The examples below are within 2% for very specific reasons: The EXACT same technician, used the EXACT same instrument, in the exact same manner, 3 to 4 weeks after his initial readings. Had he sent a technician six months later, with the same model, but different instrument, and that technician repeated the exact process, he should still be within +/- 5 to 10%.

Regardless, the Engineer was satisfied with the readings and methodology.

TAB DATA: TAB Report	3050 CFM	3125 CFM	2980 CFM
TAB DATA: Field Verified	2995 CFM	3088 CFM	3025 CFM
Variance	1.8%	2%	1.5%

Postscript:

When the “Manufacture’s Rep” showed up he explained he was a service technician and did start-up and warranty work.

He stated that he typically NEVER read airflow, so when we was asked to on this project, he ran by the distributor on the way to the project and purchased…

Engineer’s Response Upon Seeing The Instrument….

“I think we are done here.”

Lessons Learned

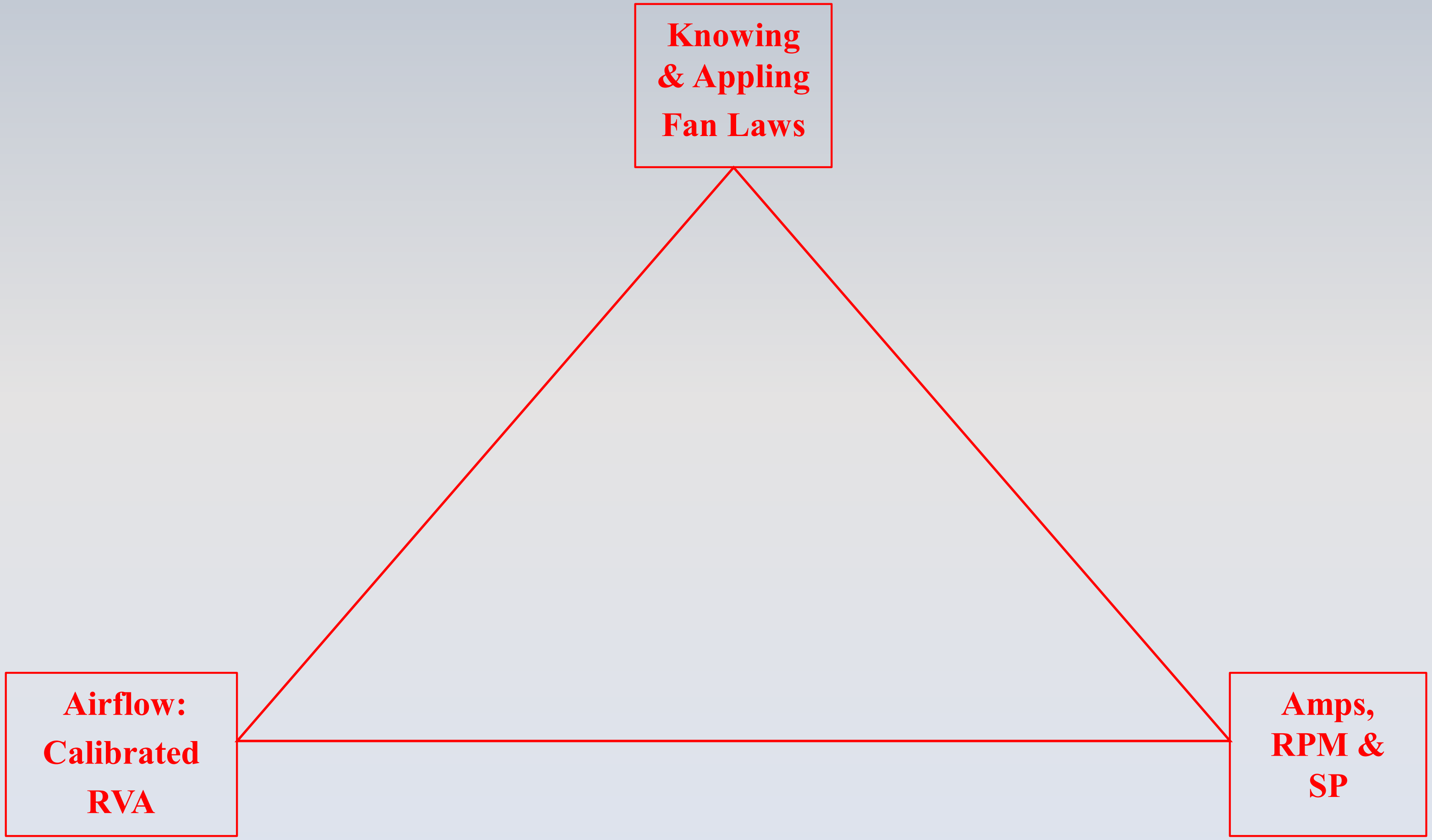
Being a TAB professional is not simply owning acceptable, calibrated instruments.

It's knowing how to use them, and how to prove those numbers via other means.

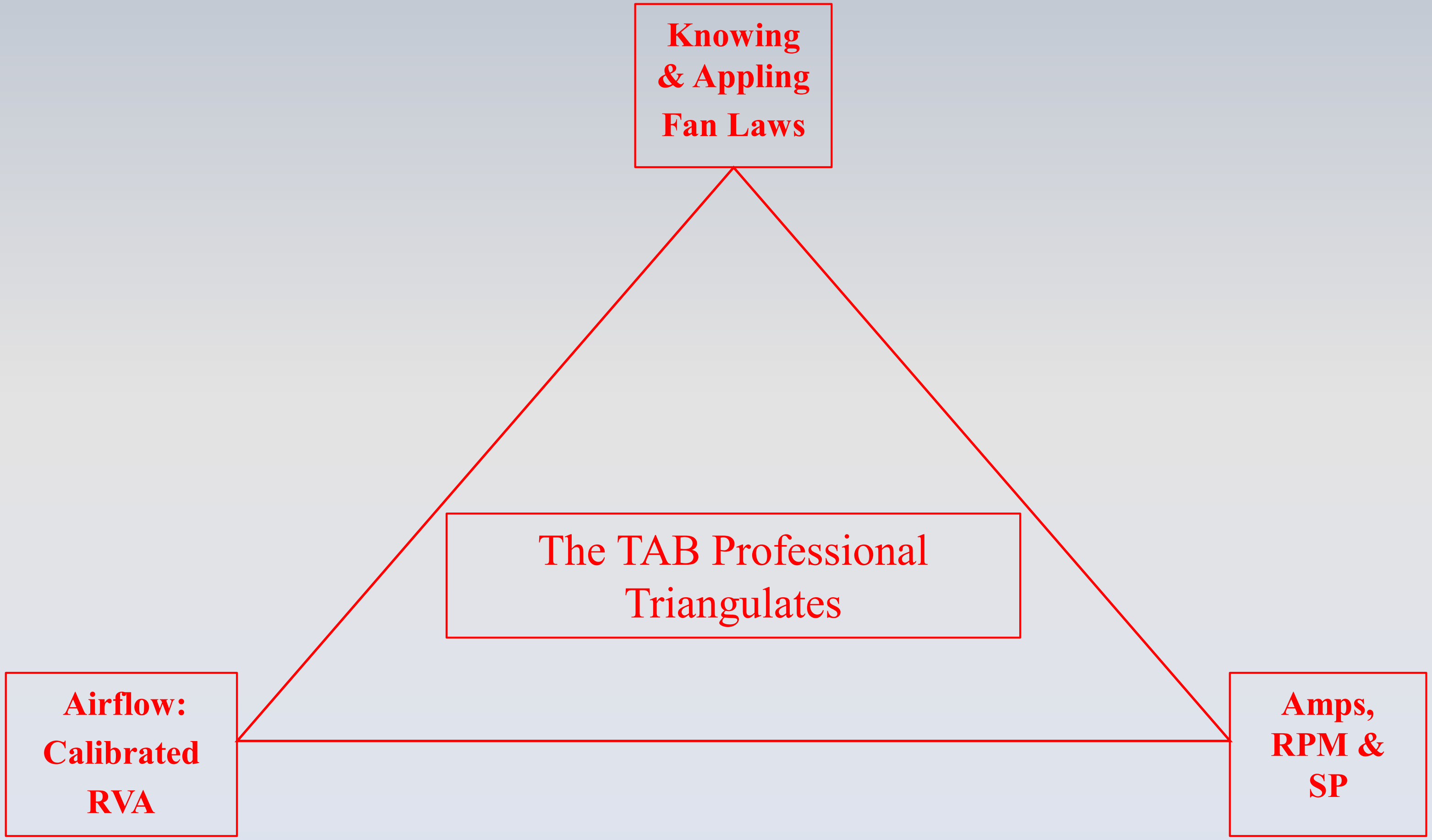
The TAB professional can not simply take one set of readings and call it a day.

The TAB professional must take a series of readings, with multiple calibrated instruments then verify those recorded values make sense.

Lessons Learned



Lessons Learned



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Lessons Learned

In that previous example, had the TAB Professional note known and been able to apply the fan laws,

He wouldn't have been able to support his data. He also wouldn't have been able to effectively communicate his data and methodology to the design team.

There's a strong possibility those fans would have been readjusted and all various problems and call backs would have ensued.

Fan and Pump Laws

In conclusion –

If you want to be among the best industry professionals in the world, you need to know the fan and pump laws.

Even more so, you need to know when and where to apply them

The more you use and apply them, the more uses you'll find.

Any Questions?

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Appendix – Fan Laws And Variations

Fan Laws, Variations, and Related Formulas

Fan Speed (RPM)	Motor Pulley Diameter (PD)	Static Pressure (SP)	Amperage (AMP)
$RPM_2 = RPM_1 \times \left(\frac{CFM_2}{CFM_1}\right)$	$PD_2 = PD_1 \times \left(\frac{CFM_2}{CFM_1}\right)$	$SP_2 = SP_1 \times \left(\frac{CFM_2}{CFM_1}\right)^2$	$AMP_2 = AMP_1 \times \left(\frac{CFM_2}{CFM_1}\right)^3$
$CFM_2 = CFM_1 \times \left(\frac{RPM_2}{RPM_1}\right)$	$CFM_2 = CFM_1 \times \left(\frac{PD_2}{PD_1}\right)$	$CFM_2 = CFM_1 \times \sqrt{\frac{SP_2}{SP_1}}$	$CFM_2 = CFM_1 \times \sqrt[3]{\frac{AMP_2}{AMP_1}}$
---------------	$PD_2 = PD_1 \times \left(\frac{RPM_2}{RPM_1}\right)$	$SP_2 = SP_1 \times \left(\frac{RPM_2}{RPM_1}\right)^2$	$AMP_2 = AMP_1 \times \left(\frac{RPM_2}{RPM_1}\right)^3$
$RPM_2 = RPM_1 \times \left(\frac{PD_2}{PD_1}\right)$	---------------	$SP_2 = SP_1 \times \left(\frac{PD_2}{PD_1}\right)^2$	$AMP_2 = AMP_1 \times \left(\frac{PD_2}{PD_1}\right)^3$
$RPM_2 = RPM_1 \times \sqrt{\frac{SP_2}{SP_1}}$	$PD_2 = PD_1 \times \sqrt{\frac{SP_2}{SP_1}}$	---------------	$AMP_2 = AMP_1 \times \sqrt{\frac{SP_2}{SP_1}}^{\,3}$
$RPM_2 = RPM_1 \times \sqrt[3]{\frac{AMP_2}{AMP_1}}$	$PD_2 = PD_1 \times \sqrt[3]{\frac{AMP_2}{AMP_1}}$	$SP_2 = SP_1 \times \sqrt[3]{\frac{AMP_2}{AMP_1}}^{\,2}$	---------------

Thank You!

From National Comfort Institute

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