Fundamentals of Test & Balance for Engineers, Cx & Energy Providers

AABC Commissioning Group

AIA Provider Number 50111116

Fundamentals of Test & Balance for Engineers, Cx & Energy Providers

AIA Course Number CXENERGY1528

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Course Description

In this practical, information-packed session, attendees will learn about many of the key test and balance issues—from precise specifications, to duct leakage testing, to pump- and fan-curve considerations—that if properly addressed in cooperation with an independent TAB firm can ensure that any project goes more smoothly.

Learning Objectives

At the end of the this course, participants will be able to:

1. Participants will explore the proper use and limitations of the TAB instrumentation to ensure an efficient project.

2. Participants will classify what is accurate, useful and meaningful data that is obtained in the field vs. laboratory data for use in their project.

3. Participants will be able to accurately distinguish what can be accurately and what cannot be accurately measure in the field in an HVAC system.

4. Participants will be able to determine schedule challenges with projects including 31 access, balancing device location and HVAC system operation.

Recommendations Overview

- Specification Issues
- Fan Curves
- Traverse Locations & Alternatives
- System Effect
- Pump Curves
- Pump Flow Measurement
- Equipment Considerations
- Project Issues

Specification Issues

- The specification document indicates that an **AABC-certified TAB agency** must perform the work.
  - Only AABC requires that its members be **INDEPENDENT**, with no other ties to the project.
  - List the TAB Agencies approved to bid the project.

- The specification clearly defines the **systems to be balanced**. List a schedule of equipment that requires TAB work.

Specification Issues

- The specification clearly defines the **scope of work** pertaining to the systems to be balanced:
  - Create a performance specification that relates to the project and data required.

Specification Issues

- Try to think of **how data will be obtained and what data will be required** before specifying the requirements.
  - Will the requested data be accurate, repeatable and meaningful?
- **Avoid ±5% tolerances**
  - For most projects, overly tight tolerances add to the cost, but not to system performance.
  - Reserve tight tolerances for special applications, not comfort cooling/heating.
  - The TAB Equipment manufacturer's tolerances sometimes exceed the specification tolerances.

Specification Issues

- **Coordinate** controls, sheet metal, and insulation specifications with TAB specification.

  Insulation specification requires that:
  - All water test ports are accessible.
  - All balancing damper handles are exposed and visible on externally insulated ductwork.
  - Water flow measuring stations need complete access from insulation to verify sizes and models. The tags sent with the flow measuring stations may be used, but verification of the correct tag needs to be verified (on the valve body), especially automatic balancing valves.

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Specification Issues

- Control specification requires that:
  - Access to the control system is made available to the TAB agency and any required hardware/software is provided by the controls contractor at no additional expense to the owner or TAB agency.

Specification Issues

- **Sheave changes** are NOT automatically the responsibility of the mechanical contractor or TAB agency.
  - It is difficult to define who is responsible -- Manufacturer, contractor, engineer? How many are required? At bid time, sheaves are an unknown cost and unknown quantity.
  - Sheave changes for fans should be included as an allowance in the project or handled as a **cost plus change order**.

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Specification Issues

- Avoid **"catch-all" clauses**.
  - *Do:* Clearly show the requirements for balancing dampers, balancing valves, and/or test ports on the plans and details.
  - *Don't:* Use a "catch-all" statement in the specifications to cover those requirements.
  - *Note:* Remember that furnishing and installing dampers and valves are NOT the responsibility of the TAB Agency.

Specification Issues

- **Calibration** of instruments per manufacturer's recommendations. As a note, most manufacturer's are every 2 years.

- **Identify each VAV box** (Fans, AHUs, HPs, etc.) with a separate identification number.
  - The DDC system should use same identification/number for each piece of equipment (VAV-1-1, VAV-1-2, etc.).

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Specification Issues

- Clarification on **testing of domestic water**, DI water systems, etc. is required.
  - Some TAB equipment manufacturers prohibit the use of their equipment on potable water systems due to potential contamination.
  - Consider installing temperature sensors on the domestic hot water recirculation loop that can report the temperatures to the DDC system.

- **Plumbing pumps or fire pumps**: If these are systems that cannot maintain an established water flow, then the water flow cannot be measured. *(See previous note.)*

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Specification Issues

- **Duct leakage testing** needs to be coordinated in the specification.
  - Who does it?
  - How many tests are required?
  - What standard is it done to?
- If required, be specific about **what sound (& vibration?) data is required** and where readings are to be taken.

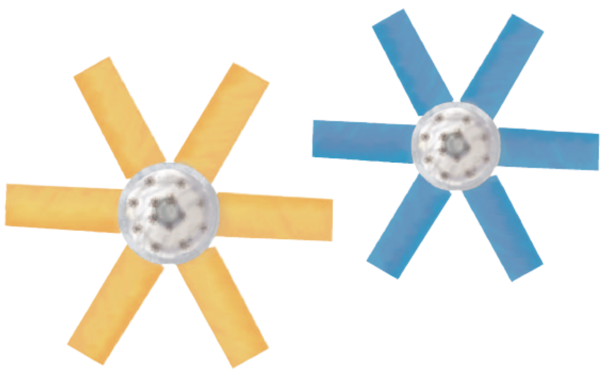
Fan Curves

- Fan curves
  - AMCA Tested
  - Produced under laboratory conditions
  - Free inlet
  - Straight discharge
  - Ideal traverse plane
  - Multiple speeds-extrapolated data
  - Standard temperature & pressure (STP)
  - Normal manufacturing tolerances

- Know the **limitations** of fan curves

Fan Curves

- *ASHRAE Journal* Article, November 2005



Fan Data Is What You See, What You Get?

By Kim G. Osborn, Associate Member ASHRAE

It happens occasionally that even after taking great care in design, the air handler turns out to be louder than expected or the airflow is less than design. This article examines some discrepancies that can occur between catalog data and the actual performance.

At first it might seem strange that, with well-established testing standards, major differences can exist between the catalog data and the performance of the fan in application. A number of reasons exist for this.

Not every wheel size is tested, and those tested are run at a limited number of speeds. Fan testing is time consuming and expensive. It is generally not practical to test all sizes or to test each size at a large number of speeds. Fan engineers strive to present the most reliable selection information they can, but due to gaps in the test series, not all sizes and operating points may be reliable. The end result is that you might take great pains to design an HVAC system with critical sound and/or airflow issues, and substantially miss the design criteria because the fan data used was too optimistic.

It is becoming more important to be able to predict and control HVAC sound. Key to this goal is knowing the sound power spectrum of the fans used in the equipment. The designers then must either depend on the catalog data for the fans selected or measure the fans' sound power themselves. For designers without an available acoustical laboratory, the latter option is often too costly. Therefore, the only option is to use the catalog numbers.

About the Author

Kim G. Osborn is CES laboratory manager at Governair Corporation, Oklahoma City.

it is rare to find 25 ft (7.6 m) of straight duct on a fan in real-world applications. Most of the differences are probably the result of unidentified system effects and what is sometimes called manufacturing variances.

The most dramatic difference between the test data and catalog data is shown in *Figure 2*. This shows the measured airflow data for two nearly identical 36.5 in. (927 mm) DWDI fans and compares these to the catalog data. The two test fans used the same size and design of wheels, inlet cones, and scrolls but had minor differences in the support frame design. Not only did these two "identical" fans have noticeably different airflow, but both fell substantially short of the cataloged airflow curve.

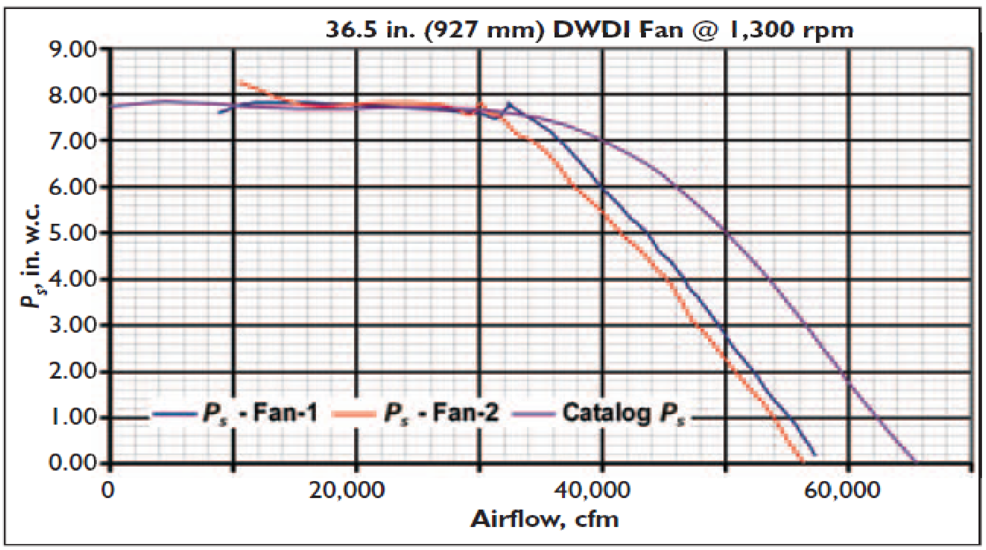


Figure 2: Measured fan airflow data compared to catalog data.

Traverse Locations & Alternatives

- **Ideal traverse plane**:
  - AABC, AMCA & ASHRAE all identify as 2 ½ diameters from condition (discharge, elbow, etc.) for up to 2500 fpm. Add 1 diameter for each additional 100 fpm.
- Rectangular Duct $E_L = (4a*b/\Pi)^{0.5}$, where "a" & "b" are the duct dimensions.

Traverse Locations & Alternatives

Example:

- 10,000 cfm, 30″ x 20″ duct, 2400 fpm
- $E_L = (4a*b/\Pi)^{0.5} = 27.6''$
  $2\ 1/2 * 27.6'' = 69.1''$
- 69.1″ (~ 6′) straight duct required

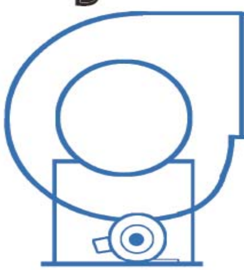
Alternatives to Traverse:

- Face velocity reading of filters, coils, hood face, etc.
- Summation of airflows at individual outlets
- Summation of calibrated VAV boxes as read at the DDC computer

System Effect

ASHRAE Journal Feb 2006 Article

System Effect Factor



How it Affects Operating Cost

By **Bernard Ratledge,** Life Member ASHRAE

For a building owner concerned with operating costs, the clearest way to document that the M&E consultant, mechanical contractor and testing, adjusting, balancing (TAB) contractor have achieved the design energy consumption is to compare the energy consumption given in the TAB equipment report with that specified in approved shop drawings.

From energy bills received for 50 new schools in Ontario, Canada (part of the 137 schools in the Dufferin-Peel Catholic district), it was evident that considerable difference existed between the predicted energy consumption and actual consumption for installed equipment. Most notable was the difference in power being consumed by fan systems, prompting further investigation of the data in the TAB report.

Unsurprisingly, the investigation revealed that at the speed measured the reported fan volume and static pressure points did not intersect on the fan performance curve at the measured speed. A considerable difference existed between the measured and true static pressure indicated on the fan performance curve that could only be attributed to the presence of a system effect factor (SEF) after all recorded data was checked for accuracy.

About the Author
Bernard Ratledge is a building systems engineer with Dufferin-Peel Catholic District School Board in Mississauga, ON, Canada. He is a member of ASHRAE Guideline Project Committee (GPC) 1, the HVAC Commissioning Process, and ASHRAE GPC 4, Preparation of Operating and Maintenance Documentation for Building Systems.

How to Avoid This Increased Operating Cost?

- By not trying to save dollars per square foot by reducing the size of the mechanical room. The increased operating cost of the poor installation is likely to be far greater than the cost of providing the space necessary to ensure a good ductwork installation.

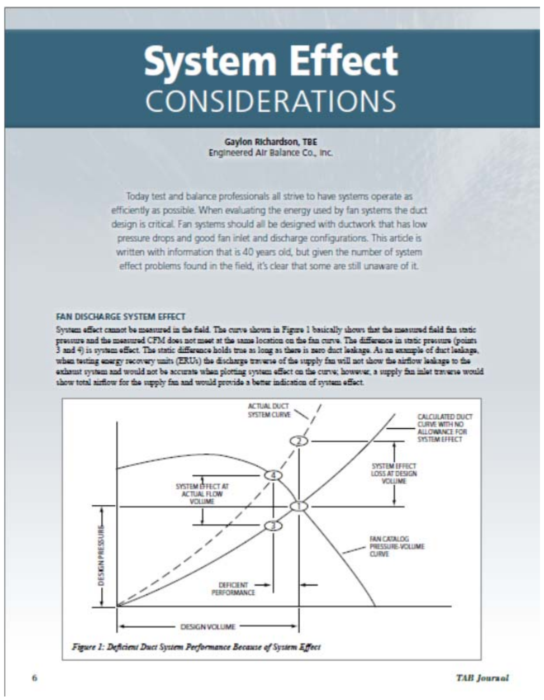
The increase in fan bhp = 16.83 – 10.06 = 6.77 (12.55 kW – 7.5 kW = (5.05 kW).

Using the same operating parameters as Example 1:

Based on the fan operating 245 days × 8 hrs/day × 7.5 = 14,700 kWh × \$0.06/ kWh = \$882 + 7.5 × \$10/kW demand × 12 = \$1,782/yr base electric cost. Revised operating cost with new motor = 245 days × 8 hrs/day × 12.55 = 24,598 kWh × \$0.06/ kWh = \$1,475.88 + 12.55 × \$10/kW demand × 12 = \$2,981.88/yr or \$1,199.88/yr increase. A life-cycle analysis based on a school useful life of 25 years, annual energy cost escalation 5%, shows an estimated total additional operating cost of \$86,489.

System Effect

- *TAB Journal* article
  Spring 2010



System Effect
CONSIDERATIONS

Gaylon Richardson, TBE
Engineered Air Balance Co., Inc.

Today test and balance professionals all strive to have systems operate as efficiently as possible. When evaluating the energy used by fan systems the duct design is critical. Fan systems should all be designed with ductwork that has low pressure drops and good fan inlet and discharge configurations. This article is written with information that is 40 years old, but given the number of system effect problems found in the field, it's clear that some are still unaware of it.

FAN DISCHARGE SYSTEM EFFECT

System effect cannot be measured in the field. The curve shown in Figure 1 basically shows that the measured field fan static pressure and the measured CFM does not meet at the same location on the fan curve. The difference in static pressure (points 3 and 4) is system effect. The static difference holds true as long as there is zero duct leakage. As an example of duct leakage, when testing energy recovery units (ERUs) the discharge traverse of the supply fan will not show the airflow leakage to the exhaust system and would not be accurate when plotting system effect on the curve; however, a supply fan inlet traverse would show total airflow for the supply fan and would provide a better indication of system effect.

Figure 1: Deficient Duct System Performance Because of System Effect

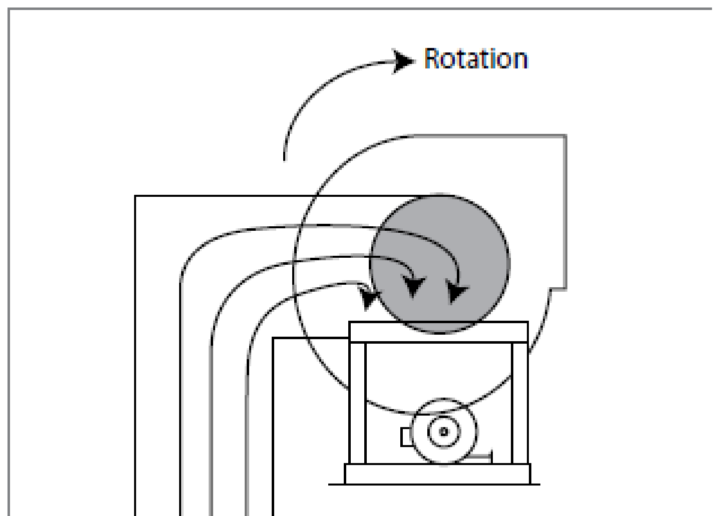
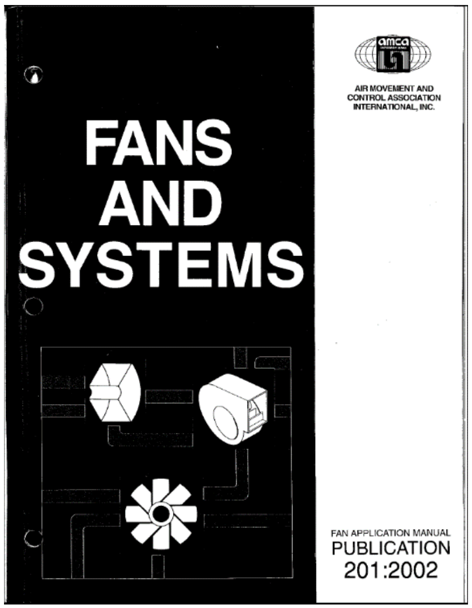
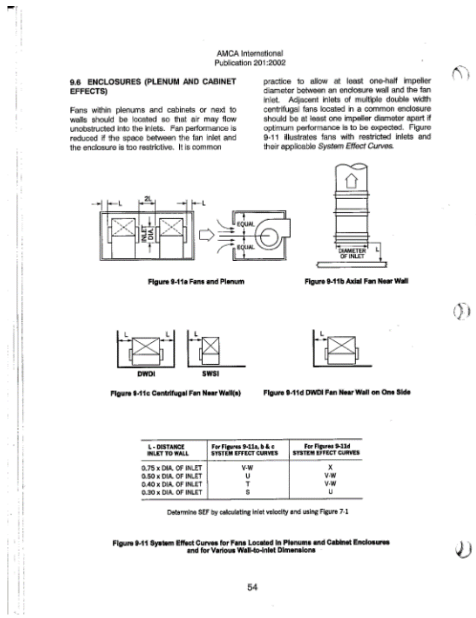


Figure 15 illustrates a poor installation with an elbow directly at the fan inlet.

System Effect





9.6 ENCLOSURES (PLENUM AND CABINET EFFECTS)

Fans within plenums and cabinets or next to walls should be located so that air may flow unobstructed into the inlets. Fan performance is reduced if the space between the fan inlet and the enclosure is too restrictive. It is common practice to allow at least one-half impeller diameter between an enclosure wall and the fan inlet. Adjacent inlets of multiple double width centrifugal fans located in a common enclosure should be at least one impeller diameter apart if optimum performance is to be expected. Figure 9-11 illustrates fans with restricted inlets and their applicable *System Effect Curves.*

Figure 9-11a Fans and Plenum

Figure 9-11b Axial Fan Near Wall

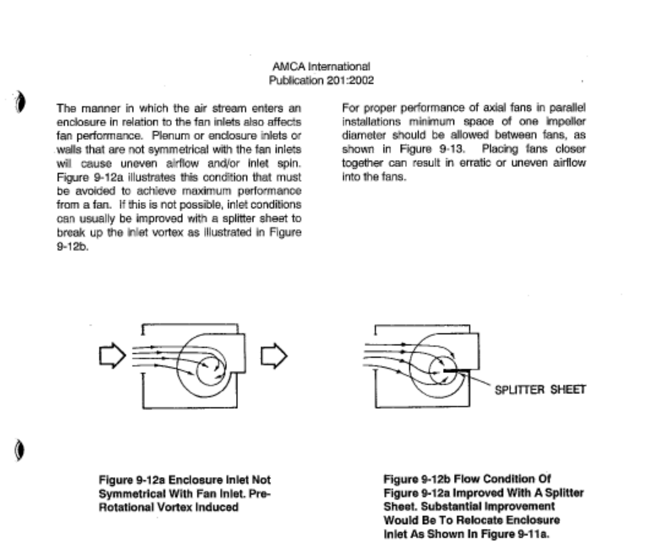
Figure 9-11c Centrifugal Fan Near Wall(s)

Figure 9-11d DWDI Fan Near Wall on One Side

L - DISTANCE INLET TO WALL	For Figures 9-11a, b & c SYSTEM EFFECT CURVES	For Figures 9-11d SYSTEM EFFECT CURVES
0.75 x DIA. OF INLET	V-W	X
0.50 x DIA. OF INLET	U	V-W
0.40 x DIA. OF INLET	T	V-W
0.30 x DIA. OF INLET	S	U

Determine SEF by calculating inlet velocity and using Figure 7-1

Figure 9-11 System Effect Curves for Fans Located in Plenums and Cabinet Enclosures and for Various Wall-to-inlet Dimensions



The manner in which the air stream enters an enclosure in relation to the fan inlets also affects fan performance. Plenum or enclosure inlets or walls that are not symmetrical with the fan inlets will cause uneven airflow and/or inlet spin. Figure 9-12a illustrates this condition that must be avoided to achieve maximum performance from a fan. If this is not possible, inlet conditions can usually be improved with a splitter sheet to break up the inlet vortex as illustrated in Figure 9-12b.

For proper performance of axial fans in parallel installations minimum space of one impeller diameter should be allowed between fans, as shown in Figure 9-13. Placing fans closer together can result in erratic or uneven airflow into the fans.

Figure 9-12a Enclosure Inlet Not Symmetrical With Fan Inlet. Pre-Rotational Vortex Induced

Figure 9-12b Flow Condition Of Figure 9-12a Improved With A Splitter Sheet. Substantial Improvement Would Be To Relocate Enclosure Inlet As Shown In Figure 9-11a.

System Effect

Standard 17,500 CFM Packaged RTU

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Pump Curves

Design Requirements:

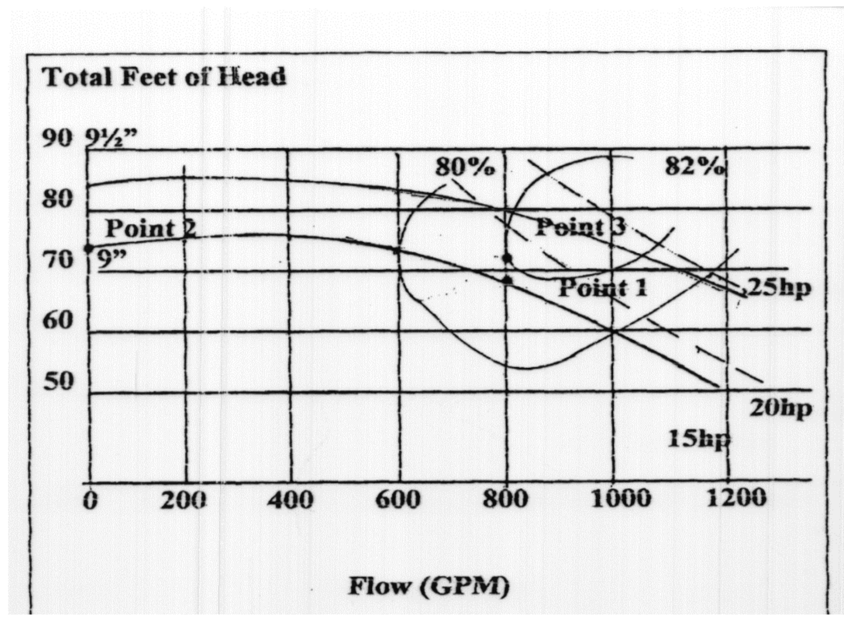
- 800 gpm @ 68'
  9" Impeller, 20 hp motor, 5BC,1750 rpm (Point 1)

Field Measurements:

- Shutoff ΔP = 73' (Point 2)
- Operating ΔP = 70.0'

Results:

- Actual: 700 gpm w/9" imp
- 12.5% below design
- Flat Pump Curve – Hard to interpolate.
- Utilize measured flows at terminals or branches to determine pump total.



Pump Curves

Design Requirements:

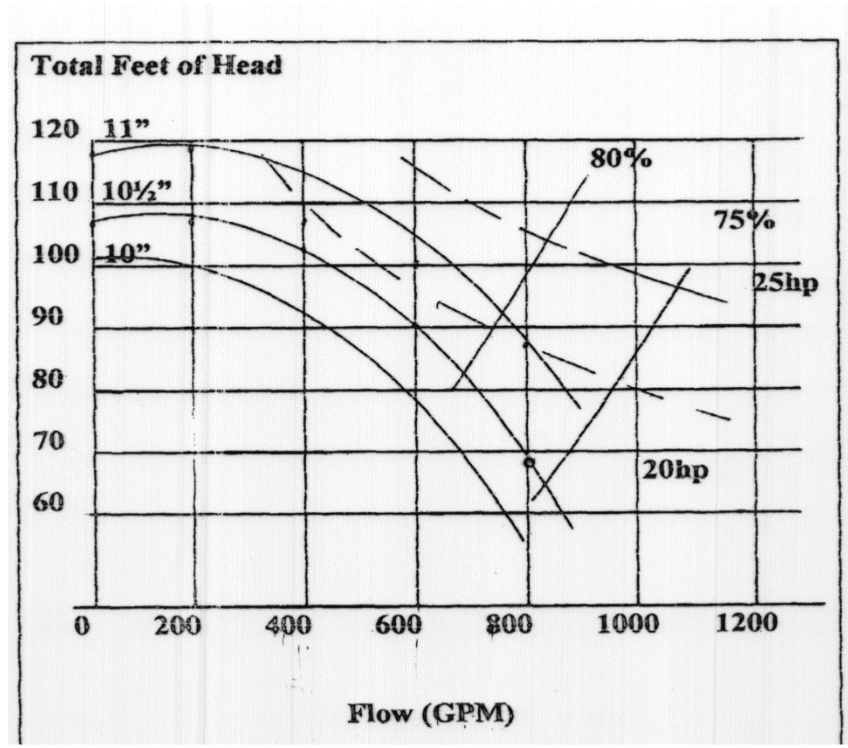
- 800 gpm@ 68′
  10-3/8″ Impeller, 20 hp motor, 4E, 1750 rpm

Field Measurements:

- Shutoff ΔP = 104′
- Operating ΔP = 72′

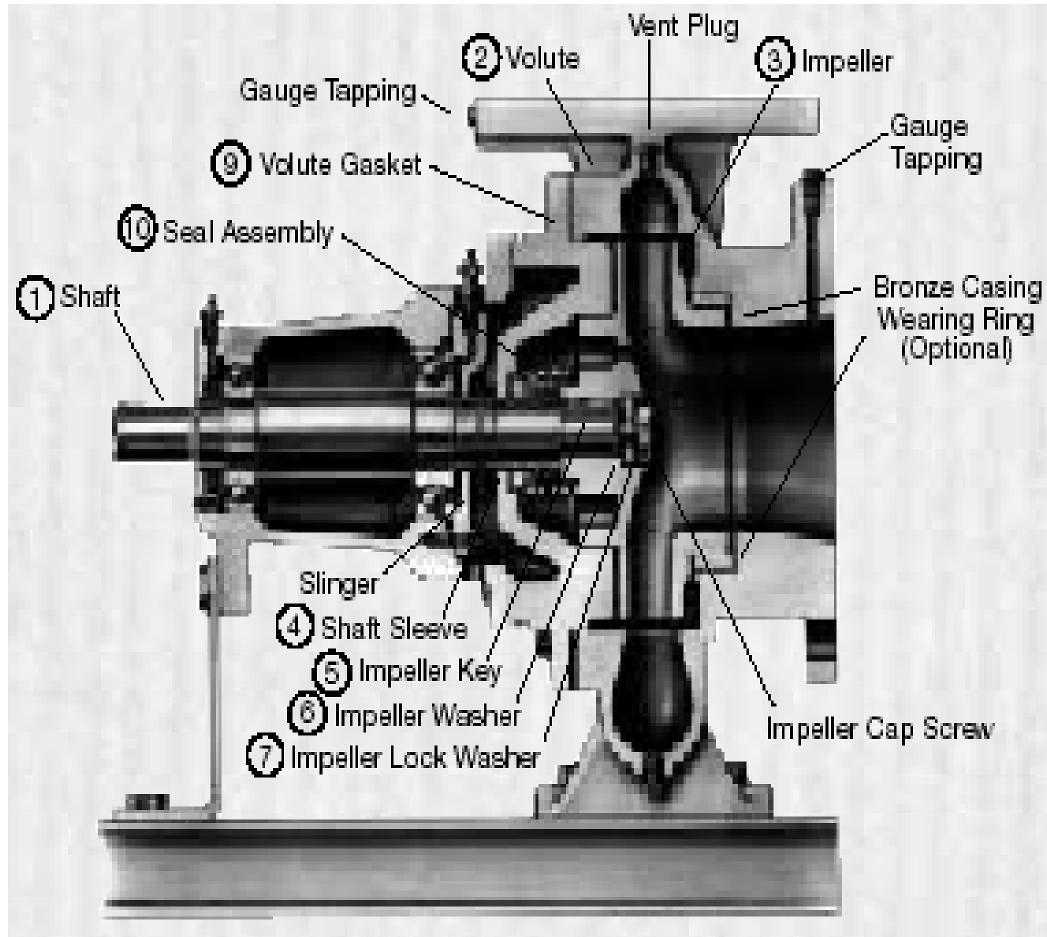
Results:

- Actual: 775 gpm w/10-3/8″ imp
- 3.1% below design
- Steep Pump Curve – Immediate Resolution.



Pump Flow Measurement

- Provide test ports/pump taps at the pumps (Extend outside of insulation).
- Provide a flow measuring device at the pump
  - Fixed orifice type device preferred, not MPVs, etc.



Scheduling Challenges

- There needs to be enough time allowed in the schedule for the TAB work to be completed.
- All work must be complete for TAB work to commence.
  - Clean air filters installed.
  - All strainers must be cleaned and start-up strainers removed.
  - All balancing dampers installed and 100% open.
  - All manual water valves and flow measuring stations should be 100% open.
  - Controls are complete and functional.

Scheduling Challenges

- Phased projects:
  - Remember that the TAB work is completed by HVAC system and NOT area.
  - Very seldom does the HVAC system match the "Phasing Areas."
  - Make sure that the Owner & Architect understand the possibility that the TAB work might be performed after occupancy. (Bid appropriately.)
  - Variable volume systems (air and water) can have provisions to balance partial HVAC systems. For phased projects, constant volume systems are much more difficult to address.
  - Water systems (heating & chilled) need to be reviewed for TAB scheduling.

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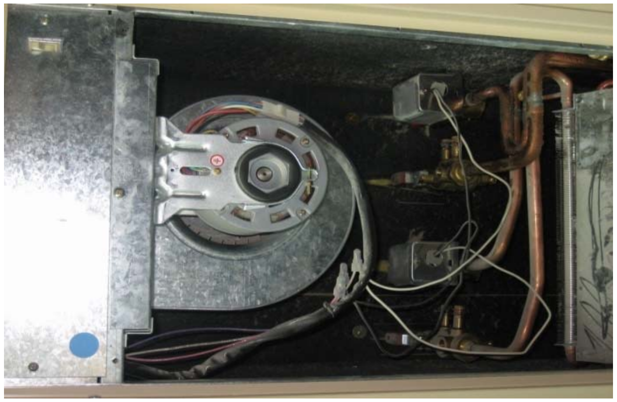
Access Challenges

- Proper clearance and access must be provided to all dampers, valves, equipment, etc. This includes the test ports on flow measuring devices and auto-flows.
  - Sheet rock ceilings, Architectural features, etc.

- Access to outlets, dampers, etc. in theatre type seating areas. How will this be accomplished? AHU is typically not in operation when scaffolding is installed.

Equipment Considerations

Examples of no access in Factory Package Automatic Balancing Valves



Why Specify AABC?

- AABC is the only test & balance organization that adheres to these Guiding Principles:

  - **Independence:**
    AABC requires its members to be 100% Independent.

  - **Guaranteed Performance:**
    All work by AABC members is covered by the National Performance Guaranty

  - **Quality Assurance:**
    AABC solicits engineer feedback on *every job*

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■ *Questions?*

This concludes The American Institute of Architects Continuing Education Systems Course

Brian Venn TBE

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About Mechanical Testing Inc.

- We have **Experience** and have been in business since 1967.
- We are largest Test and Balance company in the Northeast which allows us to **Accommodate** large projects.
- We developed and use **Customized Software** to help work efficiently, professionally, and allow some project managers and account owners to access progress on projects.
- We specialize in **Cleanroom** technology and have worked on some of the largest projects in the United States currently Global Foundries. Although, schools, hospitals, correctional facilities and large offices make up a majority of our work.
- We pride ourselves in **Customer Service**.

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