AABC Commissioning Group

AIA Provider Number 50111116

Testing HVAC Water Systems with Diversity

Course Number: CXENERGY1802

Jim Hall, PE, TBE, CxA

Systems Management & Balancing, Inc.

April 25, 2018

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Copyright Materials

Course Description

There are several types of HVAC water systems that are designed with diversity, it could be a chilled water system, heat pump loop water system, heating water system or most commonly a reheat water system. When **diversity exists** in an HVAC water system, the testing, adjusting, and balancing (TAB) of this system requires a system review and **careful consideration of the approach to the TAB process**. This presentation examines the appropriate TAB approaches to HVAC water system diversity and various testing scenarios.

Learning Objectives

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

1. Understand what constitutes diversity in a HVAC water system and its implications on the TAB process.

2. Learn to calculate the diversity of HVAC water systems and circumstances that can affect it.

3. Know the difference between a pressure dependent and pressure independent system and its implications on the TAB process.

4. Understand the relationships of airside and waterside systems to pressure dependent and pressure independent systems.

DEFINITIONS

- LET'S GET SOME TERMS DEFINED FIRST:
  - DIVERSITY
  - PRESSURE DEPENDENT
  - PRESSURE INDEPENDENT

WHAT IS DIVERSITY?

- DIVERSITY IN AN HVAC WATER SYSTEM IS DEFINED AS THE PERCENTAGE DIFFERENCE IN THE PUMP CAPACITY VERSUS THE CONNECTED LOAD.

- PUMP IS SIZED FOR 300 GPM AND THE TOTAL CONNECTED LOAD AT ALL TERMINAL UNITS IS 450 GPM.

  DIVERSITY = [(450-300)/450] X 100 = 33.33%

- HOW IS THE SYSTEM DIVERSITY CALCULATED DURING THE DESIGN PHASE OF THE PROJECT?

Pressure Dependent vs. Pressure Independent

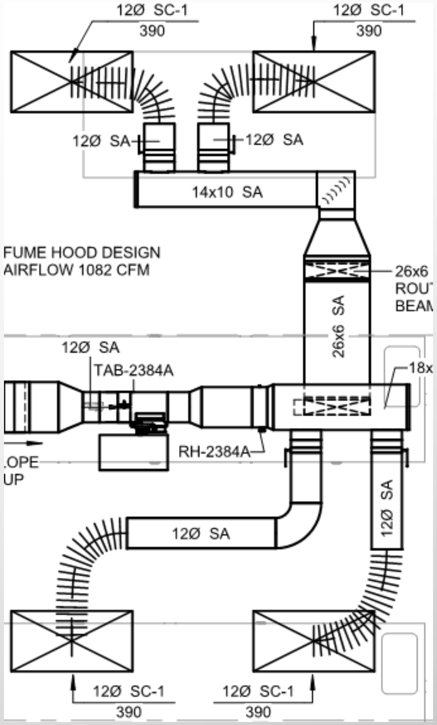
- **Pressure dependent devices** have their water flow (airflow) vary with the system pressure. As the system pressure increases the flow increases at the device and as the system pressure decrease the flow decreases at the device.

- **Pressure independent devices** have their water flow (airflow) stay at the required flow regardless of the system pressure. The pressure independent device monitors the flow (pressure) to the device and adjust the devices' control damper/valve to maintain the required flow.

Pressure Independent Air System

- In a variable volume air system, the unit fan modulates speed to maintain the static pressure set point as the variable air volume boxes modulate damper positions to maintain required airflow to the space load. The variable air volume box is:
  - **Controlling to an airflow setpoint/requirement to maintain space conditions.**
  - **Reports the airflow quantity to the BAS/DDC system.**

- When one variable air volume box or multiple variable air volume boxes change damper position, the airflow does not change at the other variable air volume boxes (as long as the system static pressure setpoint is maintained).



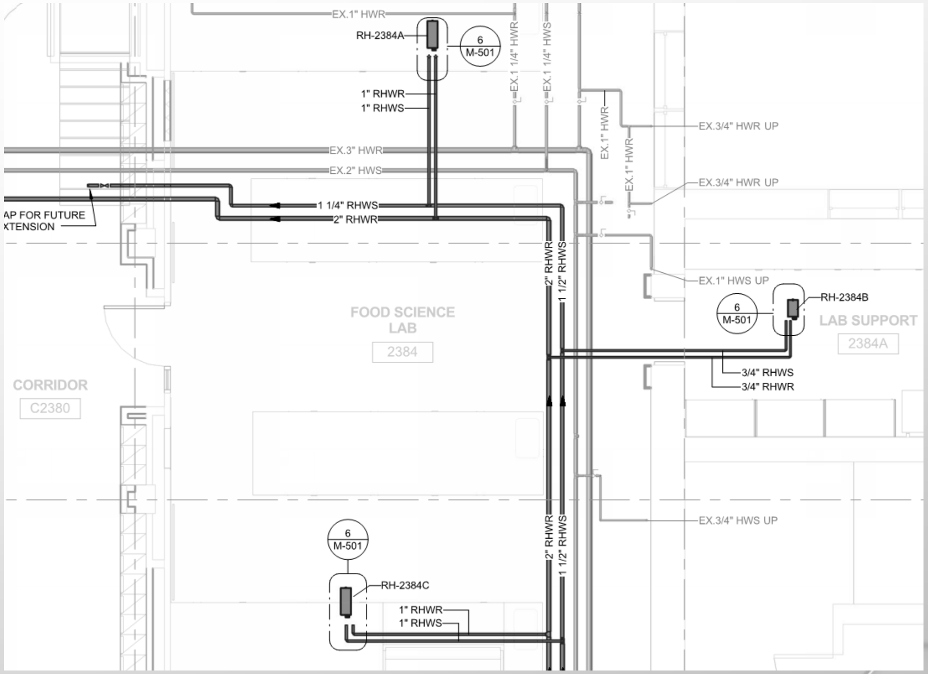
Water System: *Pressure Dependent or Independent?*

- The pump is controlled to a system differential water pressure setpoint. As the control valves open and close, the system differential pressure changes and the pump speed changes.
- **Since the control valves are controlling to maintain a space temperature or a coil/element discharge air temperature, the water flow through the coil/element can change as the system pressure and demand changes.** The actual water flow (GPM) through the coil/element is NOT (typically) being reported to the BAS/DDC system.
- Remember, the control valve is NOT controlling to a required water flow (similar to a variable air volume box), but to space temperature or a coil/element discharge air temperature.

Pressure Dependent vs. Pressure Independent

- The change in water flow at the coil/element is dependent upon:
  - What elements are opening and closing.
  - The control speed (PID loop) of the VFD controlling the pump and control valve.
  - The location of the system differential pressure sensor.
  - Elements/coils located close to the DP sensor should operate at a more consistent pressure over a range of system operating conditions.
  - The water flow at elements/coils located far from the DP sensor can vary as the system pressure at the element/coils can vary more.

The system is DYNAMIC!



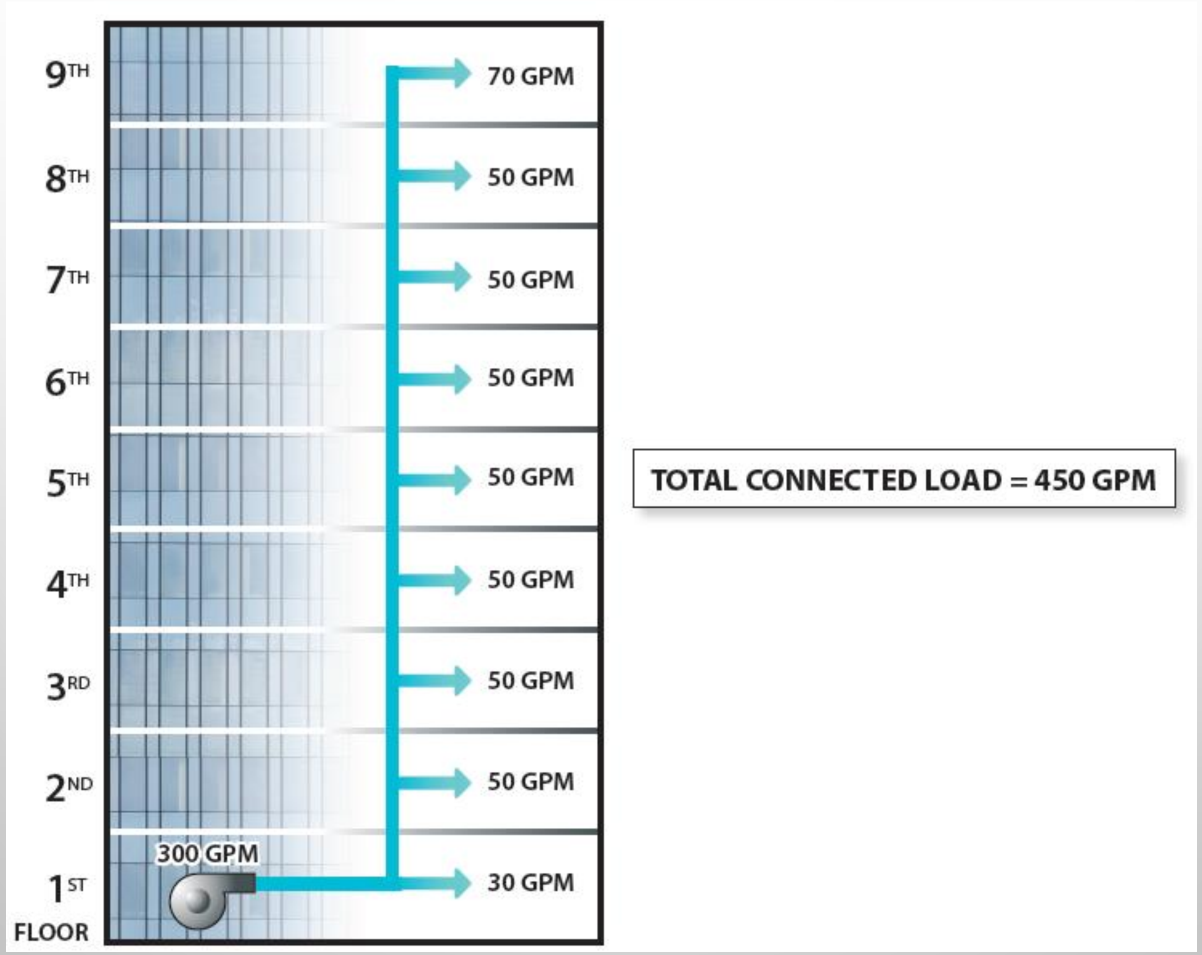
Pressure Independent Control Valves PICVs

A PICV is a device that **maintains a constant differential pressure across the control valve**. This allows for the PICV to **maintain a constant flow for a given control valve position regardless of changes in the system pressure**.

PICVs:

- **Do not have flow measuring/reporting capabilities** – some have the option.
- **Are NOT balancing devices**.
- Several have large permanent pressure loss (requires more pump energy).
- The accuracy of the flow rate at the PICV can vary from 5% to 17% depending on the manufacturer and application.
- There are changes/updates with PICVs, so stay current and understand what they are offering.

Typical High Rise Building



What to do???

- The pump (300 GPM) cannot satisfy the TOTAL system water flow requirement (450 GPM).
- The TAB agency is required to set the design water flow quantity at each coil/element?
- Can diversity be simulated?
    - *Weather load, solar load, people load, equipment load, etc. cannot be simulated. In addition, as noted before the control valve is not providing feedback to the actual water flow amount through the valve (not a VAV Box).*
- Project **scheduling** (when can the system be tested) could dictate testing procedures.

Goals of testing a water system with diversity

- Make sure that all coils/elements can obtain design requirements.
- Establish the differential pressure operating setpoint.
- Verify pump performance.
- Set up system to operate as efficiently as possible.
  - Obtain water flow to the coil/element with the greatest resistance (possibly largest GPM loads) without creating excessive resistance in the system.

ASHRAE JOURNAL DECEMBER 2017

COLUMN ENGINEER'S NOTEBOOK


Steven T. Taylor

Doubling Down on *Not* Balancing Variable Flow Hydronic Systems

BY STEVEN T. TAYLOR, P.E., FELLOW ASHRAE

In October 2002, I co-wrote a *Journal* article[1] on balancing variable flow hydronic systems where we concluded that there was, in general, no need to balance these systems—the systems were self-balancing via the two-way valve controls. In this month's column, I am doubling down: not only do variable flow systems not need to be balanced, they should not be balanced.

To be clear, this discussion relates to hydronic distribution systems with modulating* two-way valves on all or most† coils controlled by closed control loops to maintain, for example, space temperature or supply air temperature. This discussion does not apply to variable flow

mm) pipe size and below. The type of CBV we use is a ball valve with handle so it is just as reliable and convenient as a regular ball valve for isolation duty and not much more expensive. But we don't use it for manual balancing; the valve is specified to be left wide open.‡ Balancing assumes we accurately know what flow is required (more on this below) and the system can only be manually balanced for one flow condition, the design load condition, and if the pumping system is sized assuming load diversity, as most chilled water systems are, it is not even clear how to balance for that (which coils have reduced flow at the time the system load peaks?). In real systems, the coil that requires the most flow and pressure varies by hour of the day and from season to season, yet we can only manually balance for one condition. In some cases, manual balancing can lead to starved coils ... conditions. This is demonstrated in *Figure 1*

Testing Scenarios

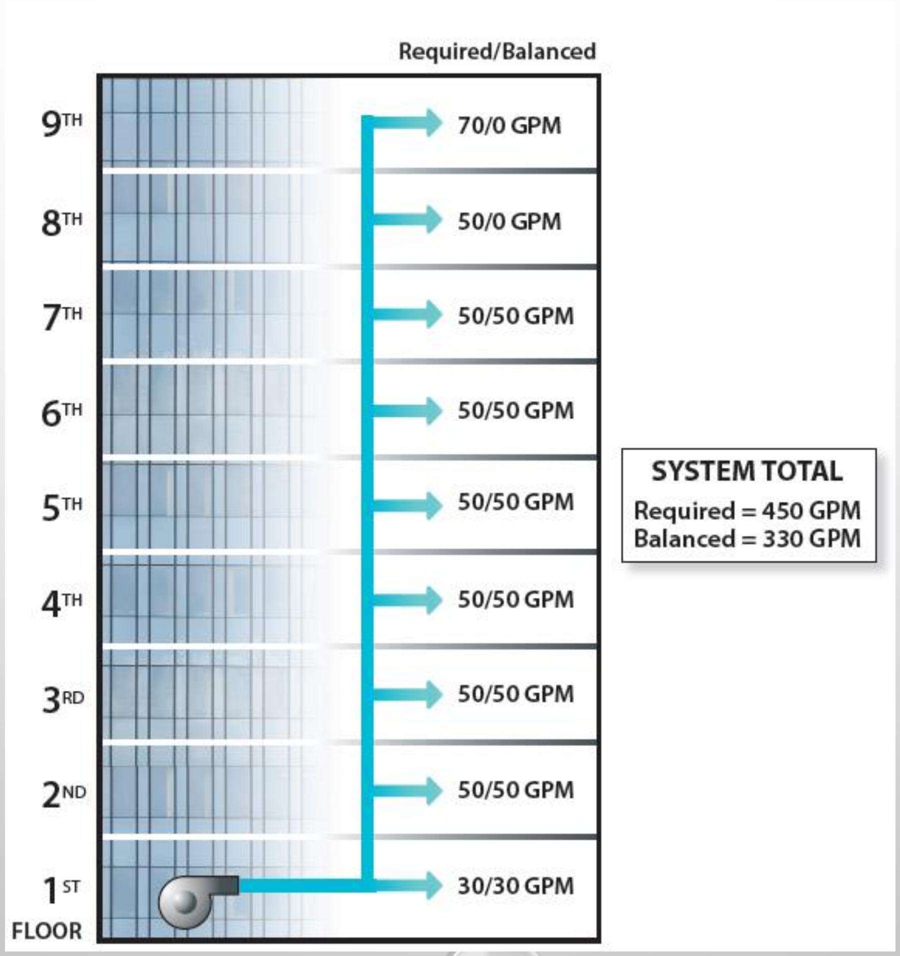
Following are "**Testing Examples**".
Please note these are **not standard procedures**, but examples to create a thought process of how an HVAC water system with diversity operates.

Testing Scenario #1
100% Load Simulation

- Open all coils/elements 100%.
- Test the pump for total water flow. *Note: Pump will probably provide more than scheduled water flow.*

- High rise example:
  - Pump that can deliver 300 GPM.
  - Connected load of 450 GPM.
  - With all control valves 100% open, if an attempt is made to balance the water flow at each coil/element there will not be enough water delivered from the pump to set each device to design water flow.

Testing Scenario #1
100% Load Simulation



Testing Scenario #2
100% Load Simulation set to % Diversity

- Open all coils/elements 100% and test the pump for total water flow.
- High rise example:
  - Pump that can deliver 300 GPM.
  - Connected load of 450 GPM.
  - With all control valves 100% open, balance each coil/element to the percentage of flow that equals the percentage of diversity (in this case 33.33%; 50 GPM = 33 GPM)

Testing Scenario #2
100% Load Simulation set to % Diversity

RESULTS:

- Water flow is now proportioned throughout the building. The building is now put under control.
- The differential pressure setpoint was set and the pump is maintaining that setpoint.
- There is added resistance to the system as balancing valves have been set (closed) to get 67% flow with a 100% open building (creates a higher required differential pressure set point).
- There is a possibility that some of coils/devices will be short of design water flow with the control valve 100% open. Also the pump total water flow could be reduced due to the added resistance on the system
- Remember that the 100% open building "should never" occur. As the building load changes, the water flow shifts around the building as required.

Testing Scenario #3
Test the system operating under control

Open all coils/elements 100% and test the pump for total water flow.

- There are several options to this method:
  - Open one floor at a time and proportionally balance the coils/elements that are open. What will this get for performance?
  - Balance each coil/element with the system under control and set to design water flow. Is this realistic in operation? Has more "pressure loss" been added to the system than necessary? Obtaining design water flow at each element should not be an issue; repeatability of balanced water flows would be an issue.
  - For a reheat system, index coil/elements to heating mode and verify discharge air temperature: record entering air temperature, leaving air temperature and entering water temperature. Remember this is a function test, not a coil capacity test. This is a snapshot of temperatures to verify functionality and heating capability. Performing a "Heat balance" and/or BTU calculations is not accurate in most cases. Spend the owner's money wisely obtaining meaningful data.

Testing Thought Process

- Determine if the system has diversity.
- Verify pump performance. Open system 100%. Note in report how the pump was tested. Pump should not overload.
- Identify the coils/heat transfer elements that could be difficult to obtain water flow. Index coil/element control valves individually (or possibly a group of coil/elements) to 100% open and verify coil functionality, i.e. Is heat obtained, does HP compressor operate, etc.
- Establish the differential pressure operating setpoint (variable flow system). Location of differential pressure sensor should be identified.
- Review the system load that will be operational during testing. Avoid testing the system with little or no demand. If a simulated demand is indexed on the system, then this should be noted in the report
- Set up system to operate as efficiently as possible. Obtain water flow to the coils/heat transfer elements with the highest water flow resistance in the system.

System Review/Planning

HVAC TAB Water System Review

Project: ______________________________ Date: __________

Engineer: ______________________________________

Controls Contractor: ________________________________

System Service: (circle choice)

Chilled Water / Condenser Water / Heating Water / Heat Pump Loop / Other: ____________

System Devices: (circle choice)

Settable Balancing Valves / Autoflows / Other: ________________

Control Valves: (circle choice) 2-way / 3-way / Other: ____________________

Location of differential pressure sensor: ________________________________

Bypass valves located in system? _____ If so, what controls the bypass valve? __________

Connected Load (GPM)					
					Total:

Pump Tag	GPM	Head	Control (SOP's)

$$\text{Diversity} = \left[\frac{\text{Connected load} - \text{pump capacity}}{\text{Connected load}}\right] = \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_$$

Balancing procedures:

1. What is under control during testing and balancing? ____________________
2. What connected load is open? ________________________________
3. What connected load is closed? ________________________________
4. EWT, EAT, LAT only? ____________________________________
5. What is O.A. temperature when balancing? ______°F

Notes: ____

Things to think about…

- How much is 0.5 GPM, 0.7 GPM, 1.2 GPM? Pour ½ gallon of water into a bucket in one minute!!
- Is the design GPM in a heating system really important to be ± 10%? Under what condition was the water flow measured originally and can that condition be repeated to compare water flows?
- According to an ASHRAE study, 90% of the heat transfer of a heating coil will be obtained at 50% water flow at 180°F water temperature.
- Is excess water flow an issue with the balancing valve 100% open on small GPM devices/elements? (Use AFLDs)
- What is the control valve controlling too? Temperature or flow?
- Are there any schedule/phasing challenges?
- Think of the measurement limitations, flat pump curves, “strainer effect”, etc.

Diversity Pointers

- Utilize discharge air temperature sensors on VAV's, coils, etc. to assist in function testing and troubleshooting. Provides the ability to trend data on the DDC.
- Utilize branch balancing devices to each floor or building and any other strategic locations. Where is it going to be difficult to get water flow or where is it easy to get water flow and restriction might be required? Are there project phasing/scheduling requirements?
- Use Automatic Flow Limiting Devices.
- Be cautious in the use of PICVs; they can require additional pumping energy and create flow issues at devices/elements.
- Make sure the control valves are sized properly.

Diversity Pointers (cont.)

- Make sure the **balancing valves are sized properly**, sized for water flow and measurement NOT pipe/line size.
- Keep an eye out for new technology, but use it with caution and proper education (Differential Pressure Controllers, PICVs, etc.)
- Would a secondary or tertiary pumping system benefit the design/operation?
- **Reverse return design** is optimum for proportioning water flows.
- Know and understand the **system design, including the sequence of operation, and the procedures for testing.**
- Focus on what is important and employ **common sense**.

Summary/Goals

- The TESTING (testing being the key word) of a water system with diversity is more of an ART than SCIENCE!! Requires thought and proper approach.
- Remember, the system is DYNAMIC. The load is constantly shifting. Let the control valve do the work. Size control valves properly.
- Try to limit the amount of resistance on the system (leave balancing valves as far open as possible) to let the pump operate as efficiently as possible. Do not be afraid to "**reset the differential setpoint**" after testing to try to minimize pump operation, trend conditions to verify system performance.

- Is occupant comfort achieved?
- Energy savings?
- Ability to troubleshoot?
- Payback on investment/equipment life?

THIS CONCLUDES THE AMERICAN INSTITUTE OF ARCHITECTS CONTINUING EDUCATION SYSTEMS COURSE

JIM HALL
SYSTEMS MANAGEMENT & BALANCING, INC.
925 SE OLSON DRIVE
WAUKEE, IA 50263
515-987-2825
WWW.HVACTAB.COM

Strainer Effect

- Setting a manual valve closed more that 40% – 50% closed creates a very small opening that will plug over time; "**<u>Strainer Effect</u>**."

  The balancing valve will need to be "cycled" open to clear the debris.

¾" Balancing Valve 100% Open

Strainer Effect

¾” Balancing Valve
50% Open

¾” Balancing Valve
25% Open