NEBB STANDARDS SECTION-9
HYDRONIC SYSTEM TAB PROCEDURES

9.1 INTRODUCTION

Testing, adjusting, and balancing (TAB) of HVAC systems can best be accomplished by following systematic procedures. The NEBB TAB procedures presented in this section are recommended current best practices for balancing HVAC systems. The procedures in this section address the majority of systems commonly installed. It is the responsibility of the NEBB Certified TAB Firm to determine appropriate procedures for systems not covered in this section.

It should be noted that the procedures listed herein may not be applicable to every project, therefore, it shall fall under the discretion of the NEBB Certified TAB Firm to determine which procedure is best utilized for the project specific systems.

9.2 PRELIMINARY SYSTEM PROCEDURES

Each type of HVAC system is designed to meet a set of performance parameters. This usually includes maximum heating capacity and maximum cooling capacity. The NEBB Certified TAB Firm should normally set-up a system in its maximum capacity, or “full load” condition prior to the TAB process. It is this condition that presents the greatest challenge to a system’s ability to meet its design hydronic flow.

Not all system types are addressed in this section. Consult with the system designer to establish the proper set-up conditions for specific systems.

The following TAB procedures are basic to all types of hydronic systems:

a) Verify that the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.

b) Confirm that every item affecting the hydronic flow in a piping system is ready for the TAB work, i.e. pumps started and operating, piping systems flushed, filled, vented, chemical treatment complete, air vents installed and operating, startup strainer screens removed and replaced with final strainer screens, etc.

c) Confirm that the automatic control devices will not adversely affect TAB operations.

d) Establish the conditions for design maximum system requirements.

e) Verify that all valves are open or set, all related systems are operating, motors are operating at or below full load amperage ratings, and pump rotation is correct.

9.3 HYDRONIC SYSTEM MEASUREMENT METHODS

9.3.1 BASIC FLOW MEASUREMENT METHODS

The appropriate techniques for flow measurement of hydronic systems shall be determined by review of the system(s) to be tested. There are five basic methods available for measuring the flow quantity in a piping system:

1. With flow meters or flow fittings,
2. With calibrated balancing valves,
3. Using pump curves
4. Using the equipment pressure loss, or
5. By the heat transfer method

It is preferable to balance hydronic systems by the use of calibrated flow measuring devices. Flow measurement is accomplished by the use of differential pressure meters and calibrated balancing valves, venturis and / or ultrasonic flow meters. This balance approach is very accurate because it eliminates compounding errors introduced by the temperature difference or equipment pressure drop procedures. Balance by flow measurement allows the pump to be matched to the actual system requirements. Proper instrumentation and good preplanning is needed.

9.3.2 CALIBRATED FLOW MEASURING DEVICES

The NEBB Certified TAB Firm shall verify that installation of the calibrated flow measuring devices is in accordance with recommended practices given by the manufacturer. Calibrated flow measuring devices include orifice plates, venturis, Pitot tubes, turbine meters, ultrasonic meters, etc. Calibrated flow measuring devices are the preferred method of flow measurement.

NOTE: Verify that the pressure units of the differential pressure gauge and the pressure units found on the flow charts provided by the manufacturer are identical. If pressure units are not the same (i.e. psi, in.w.g., ft.w.g., Pa, kPa, mm, m^3/h), pressure conversions will be required.

9.3.3 CALIBRATED BALANCING VALVES

The three types of calibrated balancing valves are: *self-adjusting, adjustable orifice, and fixed orifice valves.*

Self-Adjusting Valves

A self-adjusting valve / flow sensing device utilizes internal mechanisms that constantly change internal orifice openings to compensate for varying system differential pressures while maintaining a preset flow rate. No external adjustment is available with this device. Pressure taps, providing measurement of valve differential pressure, allow measurements of the system flow.

The NEBB Certified TAB Firm shall verify the valve flow rating from the data tag, and verify by differential pressure measurements, if available, that the pressure drop across the valve is within the control range of the valve.

Adjustable Orifice Valves

Some calibrated balancing valves are adjustable orifice devices. A chart or graph, provided by the valve manufacturer, indicates actual flow rates at various valve positions and differential pressures. Measurement of the actual flow requires knowledge of the valve position, valve size, and pressure differential of the valve.

Fixed Orifice Valves

Some calibrated balancing valves are fixed orifice devices. A chart or graph, provided by the valve manufacturer, indicates actual flow rates at various valve positions and differential pressures. Measurement of the actual flow requires knowledge of valve size, and pressure differential of the valve.

9.3.4 PUMP CURVE METHOD

Actual system flow can be determined with the use of a certified pump curve. If a certified curve is not available, pump flow may be approximately quantified by a catalog pump curve. Pump pressure readings shall be taken at the same test locations used by the manufacturer.

The pump impeller size is verified by measurement of the pump shut-off differential head. The shut-off head value is compared to pump curve data to determine the size of the pump impeller. Pump total head is determined by calculating the difference between the pump discharge pressure and pump suction pressure. Using the total head, in appropriate units, determine the pump water flow from the corrected pump curve established previously. If available, verify the pump curve data with data from flow meters and/or calibrated balancing valves.

9.3.4 EQUIPMENT PRESSURE LOSS METHOD

System flow rates may be calculated by using the HVAC equipment pressure loss, provided that certified data is obtained from the equipment manufacturer indicating rated flow and pressure losses; and provided that there is an accurate means for determining the actual equipment pressure losses. Equipment pressure readings shall be taken at similar test locations used by the manufacturer. Inaccurate measurements will result if dirt, debris, or scaling is present. Measurements will also be inaccurate if the test ports are placed such that the measured pressures include pressure drops across valves, elbows, tees, etc. If available, verify the equipment pressure loss data with data from flow meters and / or calibrated balancing valves.

When the design criteria of the equipment and the pressure loss are known, the flow rate may be calculated by using the following equation:

Equation 9.1 $Flow_2 = Flow_1 \times P_2 / P_1$

Where:

- $Flow_2$ = **calculated flow**
- $Flow_1$ = **rated flow**
- P_2 = **measured differential pressure**
- P_1 = **rated differential pressure**

9.3.5 Heat Transfer Method

Approximate flow rates may be established at heating and cooling terminal units by using both air and hydronic measured heat transfer data and the following equations. Each equation determines the total heat transfer rate of the terminal unit at the time of testing, and then the flow rate is calculated based upon the fluid heat transfer rate (water temperature difference).

For Standard Air (sensible heat):

	(US)	(SI)
Equation 9.2	$Q = 1.08 \times cfm \times \Delta t$	$Q = 1.23 \times L/s \times \Delta t$

Where:

- Q = **Heat flow in Btuh (Watts)**
- cfm = **Cubic feet per minute**
- L/s = **Liters per second**
- Δt = **Temperature difference - °F (°C)**

For water:

	(US)	(SI)
Equation 9.3	$Q = 500 \times gpm \times \Delta t$	$Q(W) = 4190 \times L/s \times \Delta t$ $Q\,(kW) = 4190 \times m^3/s \times \Delta t$

Where:

- Q = **Heat flow in Btuh (Watts or kilowatts)**
- gpm = **Gallons per minute**
- L/s = **Liters per second**
- m^3/s = **Cubic meters per second**
- Δt = **Temperature difference -°F (°C)**

Note that in Equation 9.3, the value of 500 (4190) is a constant that is used specifically for water. This constant will change when the system medium is other than water, such as a glycol mixture, steam, or refrigerant.

WARNING: This method can be used to verify that some flow is actually occurring at the measurement location. It is important to note that the temperature difference method will most likely result in significant uncertainty in the actual flow rates. This is an unavoidable consequence of the compounding of measurement errors in the field.

9.4 BASIC HYDRONIC SYSTEM PROCEDURES

Balancing hydronic systems may be accomplished in various ways. Two acceptable methods for balancing systems are presented. These methods are appropriate for all hydronic systems.

Regardless of the method, the objectives remain the same and the system will be considered balanced in accordance with NEBB procedural standards when:

a) All measured hydronic flow quantities are within ± 10 percent of the design hydronic flow quantities unless there are reasons beyond the control of the NEBB Certified TAB Firm. Deficiencies shall be noted in the TAB report summary.

b) There is at least one path with fully open balancing valves from the pump to a terminal device. Additionally, if a system contains branch balancing valves there will be at least one wide open path downstream of every adjusted branch balancing valve.

9.4.1 PROPORTIONAL BALANCING METHOD (RATIO METHOD)

The *Proportional Balancing Method* initially is described for a hydronic system ***without branch circuits:***

a) Verify that all balancing, control, and isolation valves are wide open.

b) Determine total system volume by the most appropriate method.

c) Calculate the percentage of actual hydronic flow to design flow requirements.

d) Adjust the pump to approximately 110% of design flow, if possible.

e) Measure the flow at all balancing valves.

f) Compute the ratio of measured flow to design flow for each terminal unit.

g) The balancing valve serving the terminal unit at the lowest percentage of design flow is not adjusted in this procedure.

h) Adjust the balancing valve serving the terminal unit with the next (second) lowest percentage of design until both terminal units are the same percentage of design. These terminal units are now in balance.

i) Adjust the balancing valve serving the terminal unit with the next (third) lowest percentage of design until all three terminal units are at the same percentage of design, and in balance.

j) Continue this procedure until all remaining terminals have been adjusted to be in balance at approximately the same percentage of design flow.

k) If necessary, adjust the pump volume to set all terminals at design flow ±10%.

l) Re-measure all terminal units and record final values.

m) Mark or set all memory stops on all of the balancing valves so that the adjustment may be restored if necessary.

Where a hydronic system ***has branch circuits with branch balancing valves***, the *proportional balancing* procedure is:

n) Follow above steps a) through f) for the terminals on each branch.

o) Compute the ratio of measured branch flow to design branch flow.

p) The balancing valve serving the branch at the lowest percentage of design flow is not adjusted in this procedure.

q) Adjust the balancing valve serving the branch with the next (second) lowest percentage of design until both branches are the same percentage of design and in balance.

r) Adjust the balancing valve serving the branch with the next (third) lowest percentage of design until all three branches are at the same percentage of design, and in balance.

s) Continue this procedure until all remaining branches have been adjusted to be in balance at approximately the same percentage of design flow.

t) If necessary, adjust the pump volume to set all branches at design flow, ±10%.

u) Perform the proportioning techniques specified in above steps a) through m) for the terminal units on each branch.

v) Re-measure all terminal units and record final values.

w) Mark or set all memory stops on all of the balancing valves so that the adjustment may be restored if necessary.

9.4.2 Stepwise BALANCING Method

The *Stepwise Method* initially is described for a hydronic system ***without branch circuits*****:**

a) Verify that all balancing, control, and isolation valves are wide open.

b) Determine total system volume by the most appropriate method.

c) Calculate the percentage of actual hydronic flow to design hydronic flow.

d) Adjust the pump volume to approximately 110% of design flow if possible.

e) Measure the flow at all balancing valves.

f) Starting at the pump, as the terminal units closest to the pump will typically be the highest, adjust the balancing valves to a value approximately 10% below design flow requirements.

g) As the adjustment proceeds to the end of the system the remaining terminal unit flow values will increase.

h) Repeat the adjustment passes through the system until all terminal units are within ±10% of design flow requirements and at least one balancing valve is wide open.

i) If necessary, adjust the pump volume to set all terminal units at design flow, ±10%.

j) Re-measure all terminal units and record final values.

k) Mark or set all memory stops (see Section 1, *Definitions*) on all of the balancing valves so that the adjustment may be restored if necessary.

Where a hydronic system ***has branch circuits with branch balancing valves***, the *Stepwise* procedure is:

l) Follow above steps a) through e) above for the terminal units on each branch.

m) Compute the ratio of measured branch flow to design branch flow.

n) Starting at the pump, as the branches closest to the pump will typically be the highest, adjust the branch balancing valves to a value approximately 10% below design requirements.

o) As the adjustment proceeds to the end of the system the remaining branch flow values will increase.

p) If necessary, adjust the pump volume to set all branches at design flow, +/- 10%.

q) Balance the terminal units on each branch as described in above steps e) through i) above.

r) Re-measure all terminal units and record final values.

s) Mark or set all memory stops on all of the balancing valves so that the adjustment may be restored if necessary.

9.4.3 SYSTEMS WITH SELF ADJUSTING VALVES

a) Verify that all balancing, control, and isolation valves are wide open.

b) Determine total system flow by the most appropriate method.

c) Calculate the percentage of actual hydronic flow to design hydronic flow.

d) Measure the differential pressure at each self adjusting balancing valve.

9.5 HYDRONIC SYSTEM BALANCING procedures

9.5.1 BASIC PROCEDURES

The following balancing procedures are basic to all types of hydronic distribution systems:

a) Verify that the construction team responsibilities for system installation and startup, as discussed in Section 3, Responsibilities, are complete.

b) Verify that all manual valves are open or preset as required, and all temperature control (automatic) valves are in a normal or desired position.

c) Verify that all automatically controlled devices in the piping or duct systems will not adversely affect the balancing procedures.

d) With the pump(s) off, observe and record system static pressure at the pump(s).

e) Place the systems into operation, check that all air has been vented from the piping systems and allow flow conditions to stabilize.

f) Verify that the system compression tank(s) and automatic water fill valve are operating and set properly.

g) Record the operating voltage and amperage of the pump(s) and compare these with nameplate ratings and thermal overload heater ratings. Verify the speed (rpm) of each pump.

h) If flow meters or calibrated balancing valves are installed, which would allow the flow rate of the pump circuit(s) to be measured, perform the necessary work and record the data.

i) Measure the shut-off head of the operating pump by slowly closing a valve or balancing cock in the pump discharge piping. Record the discharge and suction pressures at the pump gauge connections and determine shut-off head. Preferably, one gauge should be used to read differential pressure. It is important that gauge readings be corrected to the center line elevation of the pump. Do not fully close any valves in the discharge piping of a positive displacement pump. Severe damage may occur.

j) Using shut-off head, determine and verify each pump's impeller size and operating curve. Compare this data with the submittal data curves. If the test point falls on the design curve, Proceed to the next step; if not, plot a new curve parallel with other curves on the chart, from zero flow to maximum flow. Open the discharge balancing valve slowly to the fully open position; record the discharge pressure, suction pressure and determine total operating head.

k) Using the total operating head, read the pump water flow from the previously established corrected pump curve. If available, verify the pump curve data with data from flow meters and/or calibrated balancing valves.

l) If the measured total head is greater than the design total head, the water flow will be lower than designed.

m) If the measured total head is less than design, water flow will be greater; in which case the pump discharge pressure should be increased by partially closing the discharge balancing valve until the system water flow is approximately 110 percent of design.

n) Record the suction and discharge pressures and the water flow.

o) An initial recording of the flow distribution throughout the system shall be made without making any adjustments. This can be performed by using the existing flow measuring devices, or pressure / temperature ports, in the system, including any balancing devices at equipment (i.e. chillers, boilers, hot water exchangers, hot water coils, chilled water coils, etc.).

p) Take a complete set of pressure drop measurements through all equipment and compare this with submittal data readings. Determine which circuits have high or low water flow. Low circuits may be air bound. Check and vent air if present in low flow circuits and retake readings.

q) Compare actual total system flow with design requirements.

r) Use the proportional balancing method or the stepwise method described previously to adjust the flow rates through the equipment.

s) After all final adjustments have been completed, perform a final check of the pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.

t) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

u) Record final unit data, prepare the report forms, and submit as required (see Section 5, *Standards for Reports and Forms).*

9.5.2 BYPASS VALVES

Where three-way automatic valves are used, set all bypass line balancing valves to the specified values. If there is no specified value for the bypass flow, adjust the bypassed flow to 90 percent of the design coil flow.

9.5.3 VARIABLE FLOW HYDRONIC SYSTEMS

TAB procedures for a variable flow system are similar to those for constant flow systems. The main difference is that a mechanism exists in the system to vary system flow in response to demand. Three methods of controlling variable flow systems are:

1. Controlling the pump speed by a variable frequency drive.
2. Using bypass valves.
3. Allowing the pump to operate at a constant speed on its curve.

The basic steps previously outlined form the foundation for balancing a variable flow hydronic distribution system. In this subsection, additional balancing procedures are outlined for use in balancing variable flow hydronic distribution systems.

a) Variable flow systems are balanced under simulated full load system conditions. The procedures to balance a variable flow hydronic system are:

b) Verify that the construction team responsibilities for system installation and startup as discussed in Section 3, *Responsibilities,* are complete.

c) Place the system in a simulated full load condition. If diversity is present in the system, temporary isolation of portions of the system piping and terminal units may be required.

d) Conduct the basic pump testing and flow procedures as outlined previously. If the pump is controlled by a VFD, verify the pump is operating at its rated speed.

e) The terminal units are balanced using one of the balancing methods described previously.

f) When diversity is present in the system, upon completion of balancing procedures with a portion of the system isolated, the isolated units are then opened and an equal capacity of units closed.

g) Units isolated for the initial balancing procedure are then balanced to design flow rates.

h) The value of the variable flow control setpoint shall be measured and recorded. The control contractor shall be provided with this information.

i) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

j) Record final system data, prepare the report forms, and submit as required (see Section 5, *Standards for Reports and Forms).*

Diversity is a design concept in a variable flow system that allows a system of terminal units to be served by a pump that is rated for a fraction of the total system terminal unit capacity. Variable flow systems with diversity may be encountered in TAB work.

The NEBB Certified TAB Firm should determine if the variable flow system has a diversity factor. The diversity factor is an arithmetic ratio of the pumps rated hydronic flow capacity divided by a summation of all terminal unit's design maximum hydronic flow.

Variable flow systems with diversity can be the most difficult to balance satisfactorily. Any procedure used will be a compromise, and shortcomings will appear somewhere in the system under certain operating conditions. The NEBB Qualified TAB Supervisor should expect that some fine-tuning will be necessary after the initial TAB work is complete.

9.5.4 PRIMARY-SECONDARY HYDRONIC SYSTEMS

Initial balancing should be restricted to the primary loop and its components. Secondary systems should be in full flow operation during primary loop balancing.

Primary-Secondary hydronic systems are balanced as follows:

a) Verify that the construction team responsibilities for system installation and startup as discussed in Section 3, *Responsibilities*, are complete.

b) Place the primary system in a simulated full load condition.

c) Conduct the basic pump testing and flow procedures on the primary system as outlined previously.

d) Place the secondary system in a simulated full load condition. If diversity is present in the system, temporary isolation of portions of the system piping and terminal units may be required.

e) Conduct the basic pump testing and flow procedures on the secondary system as outlined previously.

f) The terminal units are balanced using either the stepwise or the proportional balancing methods described previously.

g) When diversity is present in the system, upon completion of balancing procedures with a portion of the system isolated, the isolated units are then opened and an equal capacity of units closed. Units isolated for the initial balancing procedure are then balanced to design flow rates.

h) After all final adjustments are made, perform a final check of the pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.

i) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

j) Record final system data, prepare the report forms, and submit as required (see Section 5, *Standards for Reports and Forms).*

Primary / Secondary / Tertiary systems are balanced in a similar manner.

9.6 BALANCING SPECIFIC SYSTEMS

The basic steps previously outlined form the foundation for balancing any hydronic distribution system. In this subsection, additional or special balancing procedures are outlined for use in balancing specific types of hydronic distribution systems.

9.6.1 COOLING TOWER (CONDENSER WATER) SYSTEMS

With an open condenser water pumping system in operation, perform the following steps:

a) Verify that the construction team responsibilities for system installation and startup as discussed in Section 3, *Responsibilities*, are complete.

b) Conduct the basic pump testing and flow procedures as outlined previously.

c) Record the flow and / or inlet and outlet pressures of the tower piping if applicable. Check against the manufacturer's design information.

d) When a tower bypass control is used in the condenser water piping at the tower, measure the pressure difference with full water flow going both through the tower and / or through the bypass line. Set the bypass line balancing valve to maintain a constant pressure at the pump discharge with the control valve in either position.

e) After all final adjustments have been completed, perform a final check of the hydronic pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.

f) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

g) Record final system data, prepare the report forms, and submit as required (see Section 5, *Standards for Reports and Forms).*

9.6.2 CHILLED WATER SYSTEMS

a) Verify that the construction team responsibilities for system installation and startup, as discussed in Section 3, *Responsibilities*, are complete.

b) With pump(s) off, observe and record the system static pressure at the pump(s).

c) Energize the pumping system.

d) Conduct the basic pump testing and flow procedures as outlined previously.

e) Determine the water flow through the evaporator, and condenser if present, using flow meters, calibrated balancing valves, or pressure / temperature ports. If the measured differential pressure must be used, the flow data can be obtained from the manufacturer's submittal data curves or tables. Adjust the flow to design conditions and record the data.

f) After all final adjustments have been completed, perform a final check of the hydronic pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.

g) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

h) Record final system data, prepare the report forms, and submit as required (see Section 5, *Standards for Reports and Forms).*

9.6.3 HEAT EXCHANGERS AND BOILER SYSTEMS

Energize the hot water heater or boiler pumping system and perform the following steps:

a) Verify that the construction team responsibilities for system installation and startup as discussed in Section 3, *Responsibilities*, are complete.

b) Conduct the basic pump testing and flow procedures as outlined previously.

c) Record the water flow and / or inlet and outlet pressures of the water heater(s) or boiler(s). Check against the manufacturer's design information.

d) When a temperature control valve is used in the water piping at the boiler to control heating water loop temperature, measure the pressure difference with full water flow going both through the boiler and/or through the bypass line. Set the bypass line balancing valve, if present, to maintain a constant pressure at the pump discharge with the control valve in either position.

e) After all final adjustments have been completed, perform a final check of the hydronic pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.

f) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

g) Record final system data, prepare the report forms, and submit as required (see Section 5, *Standards for Reports and Forms).*

9.6.4 HEAT TRANSFER COMPONENTS

Heat transfer components include but are not limited to heat exchangers, fin tube radiators, coils, unit ventilators, etc.

a) Verify that the construction team responsibilities for system installation and startup, as discussed in Section 3, *Responsibilities*, are complete.

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b) Determine the water flow through all heat exchangers in all circuits using flow meters or calibrated balancing valves. If the measured differential pressure must be used, the flow data can be obtained from the manufacturer's submittal data curves or tables.

c) Adjust the flow to design conditions at all heat transfer components as discussed in Subsection 9.5.

d) After all final adjustments have been completed, perform a final check of the hydronic pressures and the flow of all pumps and equipment.

e) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

f) Record final system data, prepare the report forms, and submit as required (see Section 5, *Standards for Reports and Forms).*