Functional Performance Test

Variable Frequency Drive (VFD)
Pump Application

Secondary Hydronic Pump Application

Project: ________________________________ Date: ________________
Address: ________________________________

Commissioning Participants:
Commissioning agent (CA): ______________________ of ____________________
EMS operator: ______________________ of ____________________
VFD technician: ______________________ of ____________________
HVAC technician: ______________________ of ____________________
Owner's rep.: ______________________ of ____________________

Pumps ID:_____ _____ _____ ____ **Chilled water** (CHW) **secondary,** ___**Hot water** (HW)
Design max.: Hp: ____ GPM: ______ Head _____ Ft

VFD brand and model: ____

The following functional performance test is for a VFD controlling a variable flow hydronic system to a **constant** differential pressure (DP). *A check-mark denotes acceptance or compliance.*

I. Design Intent and Documentation Verification

___ Review the design documents and the specifications.

___ Verify that the VFD ___description, ___specifications, ___technical and troubleshooting guide and the installation, ___programming record and ___balance report are on-site.

From the design documents determine: Location for the DP measurement: ____

Control strategy for the pump:____
____

II. VFD Installation

Differential Pressure Sensor

Actual location of DP measurement__________________________________

The measurement should ideally be taken across the coil of the last branch.

____**Complies?**

Notes:

Pressure Offset (Po) Conversion: psi x 2.31 = ft H_2O

DP pump is being controlled to: _______feet [A].
Pressure rise across pump at design conditions (from balance report): _______feet [B].
Pressure offset, Po, [A] ÷ [B]= _______.
Optimally, Po should be 0.3 or less in order for the VFD and pump to be able to respond to small pressure changes and realize adequate energy savings. If Po is greater than 0.4, the DP sensor is probably located too close to the pump.

___Complies?

Balancing to Lowest Pressure

Review the HVAC balance report and verify, according to the report, that the system was balanced so the VFD controls to the lowest possible DP (that is a capacity test was performed). The controlling DP from balance reports is _________feet. At design, the corresponding VFD frequency or pump RPM from the balance report is: Pump-1 ________, Pump-2 _______; Pump-3 _____. The corresponding flow from the balance report is_______GPM. Refer to the capacity test at the end of this form for details.

___Balanced to lowest DP?

General Issues

___ Verify that any power quality mitigation measures required from the specifications have been completed.
___ Verify that there are no 3-way coil valves that may negate the value of the VFD by allowing flow to bypass the coil, except for a very small min. flow bypass.
___ Verify verbally that the acceleration and deceleration ramp time of the VFD is between one and four minutes. Actual ramp time: up _____min. down _____min. (too short of ramp times will result in "hunting" and excess modulation by the VFD; typical ramp times are 1 to 4 minutes)
___ Verify that each VFD has been integrated into the EMS as per specification.
___ Verify that the lower frequency limit is programmed to 10-30% (the lower the better).
___ Verify that the EMS monitors the DP.
___ Min.flow bypass with 2-way or constant flow valve, if present, has flow less than 2% of design flow?

III. Functional Performance Test

This test is not intended to verify that the coil valve is functioning properly, but rather that the VFD is functioning properly.

1. **Design Flow by Test and Balance (TAB).** Record in Condition 1 in Table 1 the speed, DP and total supply flow at design conditions from the TAB report.

Notes:

2. **Intermediate Flow** (coil valves partially open)**.** If current conditions are such, that the system is not expected to be in full cooling or full heating, nor be at minimum flow.

a. Read the speed, DP and the total supply flow in the secondary loop and record in Condition 3 in Table 1.

If the conditions are not in an "intermediate" position, change all space temperature set points to 4 degrees below the actual temperature in the space, for *CHW pumps* OR 4 degrees above for *HW pumps* (circle one) to simulate an approaching of thermostat satisfaction and take readings.

3. **Design Flow** (coil valves full open)**.** Using the (EMS) or other means, change all the space temperature set points to at least 10 degrees *below* the current space temperature for *CHW pumps*, OR 10 degrees *above* for *HW pumps*, so that the entire HVAC system supplied from these pumps is in full cooling (or heating, as appropriate, circle) in all zones. Observe that all coil valves are to their *design* maximum position (from the TAB report). Wait at least 20 minutes for lag time while observing:

___Does the first lag pump turn on (after a delay) when the lead pump exceeds its ______ gpm design flow?

___Does the 2nd lag pump turn on (after a delay) when the sum Lead + Lag 1 exceeds the sum of their design, ***AND*** **the DP drops to ____% or _____ feet?** (typically 80%)

a. Read the speeds, DP and the total supply flow and record in Condition 2.

4. **Minimum Flow** (Coil valves shut)**.** Change all space temperature set points to be equal to the actual space temperatures to simulate a satisfied condition, driving the boxes to their minimum and the coil valves closed. Wait at least 25 minutes.

___Do the lag pumps sequentially turn off (with a delay) when the flow is less than the design of all ***running*** **pumps?**

___Does the last pump shut off appropriately?

a. Take the frequency, pressure and flow readings and record in Condition 4.

Notes:

IV. Analysis

Table 1.

Condition	Secondary Pump No.	Speed (Hz or RPM) Reading	Speed Average	DP at Sensor (psi) Reading	DP Average	Total Flow (gpm)
1. At design flow by TAB	**Lead**					
	Lag-1					
	Lag-2					
2. At design flow (during commissioning)	**Lead**					
	Lag-1					
	Lag-2					
3. At intermediate flow (during commissioning)	**Lead**					
	Lag-1					
	Lag-2					
4. At no flow (during commissioning)	**Lead**					
	Lag-1					
	Lag-2					

Conversion: 0.434 x ft H_2O = psi, 2.31 x psi = ft H_2O

1. In Table 1, average the speed and the DP for all pumps at each of the four conditions.
2. If the speed at Condition 1 (TAB test) is not within 10% of the current test at Condition 2, all the boxes may not have been driven wide open during the Cx'g test, or the readings were taken before the lag time was complete. Investigate and repeat tests as appropriate.
   ___Less than 10% variance?
3. During operation of lead-lag pump combinations, the average DP readings at all four conditions should remain within 10% of each other. If the there is more than a 10% variance, the sensor may be faulty. (During lead-lag pump transition, the DP may appropriately vary by as much as 20%)
   ___Less than 10% variance?
4. **___At no flow, Condition 4, is the flow and DP zero or equal to the min. flow bypass?**
5. **___For the total flow readings in Table 1, are the values in Condition 2 > 3 > 4?**
6. **___Collaborative Trending**
   The system operation will, will not (circle) be trended to further verify the proper operation of the VFD. Points to be trended are listed in the Trending Request Form.
   ___From studying the trends, is the VFD is functioning properly?

Notes:

7. **Additional tests.** Refer to the chilled water systems sequence of operations tests for further collaboration on the VFD performance.

V. Training

___The training specified in the design incentive agreement has been completed.

VI. O&M Plan

___An acceptable O&M Plan has been put into place. Describe:

VII. Capacity Test

To insure that energy use is minimized, the hydronic system must be balanced at design conditions at the lowest possible differential pressure (DP) possible. This requires that the lowest possible DP at the sensor be found that will allow the delivery of design flow through the valve most difficult to satisfy. This system minimum DP found is what the VFD should control to. This is accomplished by changing the temperature setpoint for all zones to 55F for cooling coils or 85F for heating coils, causing all AHU coil valves to be calling for full cooling or heating, as applicable. Each coil's flow is then measured against the design flow. The coil that is receiving the lowest fraction of design is identified. The current DP at the controlling sensor is noted. A calculation is made, giving the DP required at the sensor to allow the identified most critical coil to meet its design flow. The equation is $DP_2 = DP_1 \times Q_2^2 / Q_1^2$. Where Q_1 = actual or fraction of design flow during capacity test. Q_2 = design flow or 1.0 if using fractions. DP_1 = DP at sensor. DP_2 = DP to control to. It is noted that if all coils were calling for full cooling simultaneously, the pump could not maintain the new DP_2 value, due to diversity pump size reduction having been made by the design engineer.

Parties required for VFD site commissioning work

Commissioning agent To witness and record the tests.
EMS operator To drive boxes open and shut by changing the set points, etc.
VFD technician To use the keypad to verify the ramp time. (unless verified at start-up, which is recommended). Sequencing the keypad to display ramp time could be done by the commissioning agent, alone after reviewing the VFD technical manual.

Notes: