

17th NATIONAL CONFERENCE ON BUILDING COMMISSIONING



EFFICIENCY • PERSISTENCE • PERFORMANCE

Control Sequence of Operation

Getting it Right from OPR to Systems Manual

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AIA Quality Assurance



Learning Objectives

- 1. Gain an appreciation for the importance of a proper sequence of operation**
- 2. Learn some of the obstacles to creating a good sequence of operation**
- 3. Learn how the sequence can be passed on and understood by the building operators.**



Controls on the Project?

Critical Questions:

- Does the owner have specific requirements for Facilities operation that have been communicated to the Engineer?
- Can the engineer effectively communicate how the equipment is to operate for purposes of bidding?
- Can the contractor determine from the sequence the hardware required?
- Can the hardware be programmed based upon the sequence?
- Can the Functional Performance Tests be extrapolated from the sequence?
- Can the Owner's staff understand the automatic controls well enough to allow them to operate as intended and not intentionally or inadvertently change the sequence?

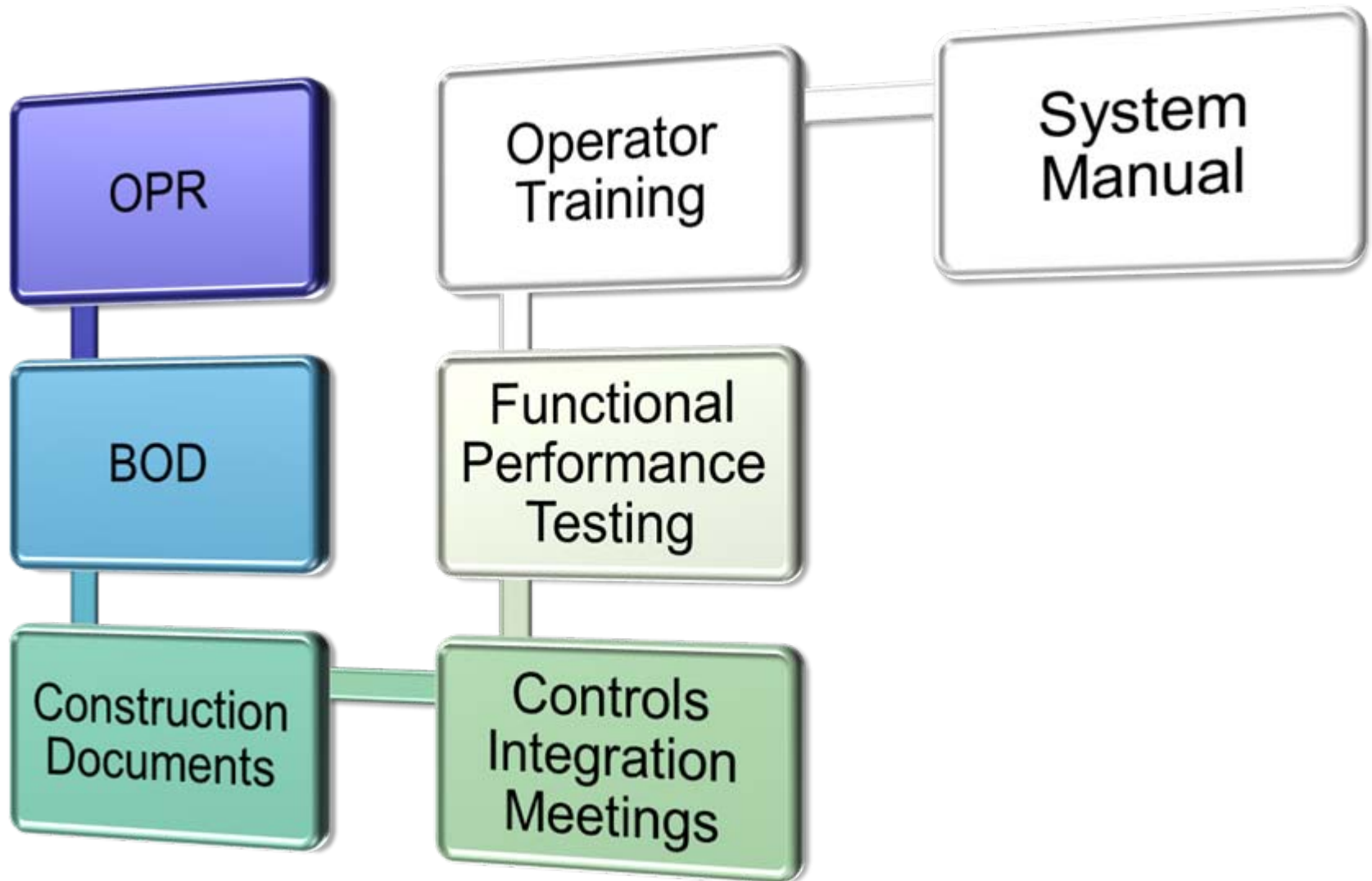


Control Sequence of Operation

Definition:

- A narrative description of how the building system components shall automatically and optimally operate to provide comfort, ventilation, and energy savings.

Sequence of Operation





Owner's Project Requirements (OPR)

Documents the functional requirements of the facility and expectations of its use and operation.

- Occupancy
- Use of the Facility
- Energy Performance
- Environmental Performance
- Thermal Comfort
- Indoor Air Quality
- Quality of Materials and Equipment

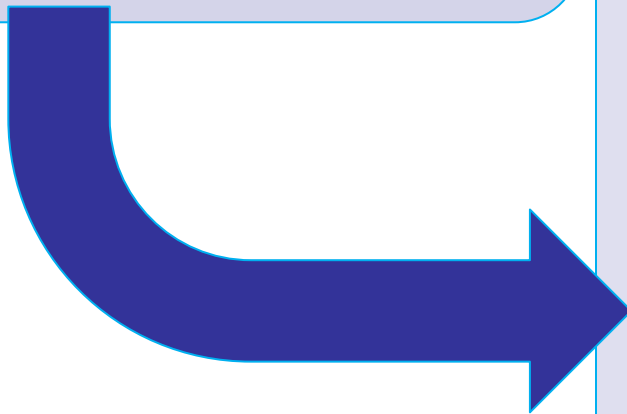
Basis of Design (BOD)

A narrative of what the design professional has developed to respond to and meet the Owner's Project Requirements. The BOD will be qualified with assumptions and criteria used.

Increasing Detail

OPR Concept

- The Owner has a site and wishes to use district chilled water for cooling purposes, as the cost is lower than on-site generation. They do have some critical cooling needs, though, and would like some type of back-up if the district chilled water fails.



BOD Detail

- The engineer suggests that a primary/secondary system be installed, with a modulating valve on the Chilled water return to the district. The return water to the district will be monitored to maintain a 10 degree F temperature difference from the supply. Under low load conditions, the primary return water valve will modulate to bypass the water back into the secondary system (circulated by secondary CHW pumps), maintaining the 10 degree differential. The district supply will be monitored for flow and for high temperature. If there is a loss of flow and/or the supply temperature rises too high, the building system will isolate from the district water and energize the on-site mechanical cooling in series in the secondary system. The Building Automation System (BAS) will disable all non-critical cooling loads by closing their cooling valves, as the on-site capacity is only designed for the loads of critical areas. The BAS will automatically check for the return of district chilled water by opening the isolation valve for 5 minutes every hour to 5% of full flow to see if temperature or flow conditions can be met.

Obstacles to Good Sequence

Not Enough Fee

Not Enough Knowledge

Schedule (compressed)

Sequence left to other
team members

No OPR or BOD for the
job – LEED EA Prereq 1
only (no Enhanced Cx)





SOP with Lack of Detail

- AHU-1-1 will run during occupied hours. The gas heat and mechanical cooling will be modulated, as necessary to maintain the space temperature set points.
- What are the occupied hours? What will the unit do outside of those hours? How does the unit transition from occupied to unoccupied and back? The mechanical unit schedule notes that the unit comes with an airside economizer – how should this be controlled?

Sequence as Published

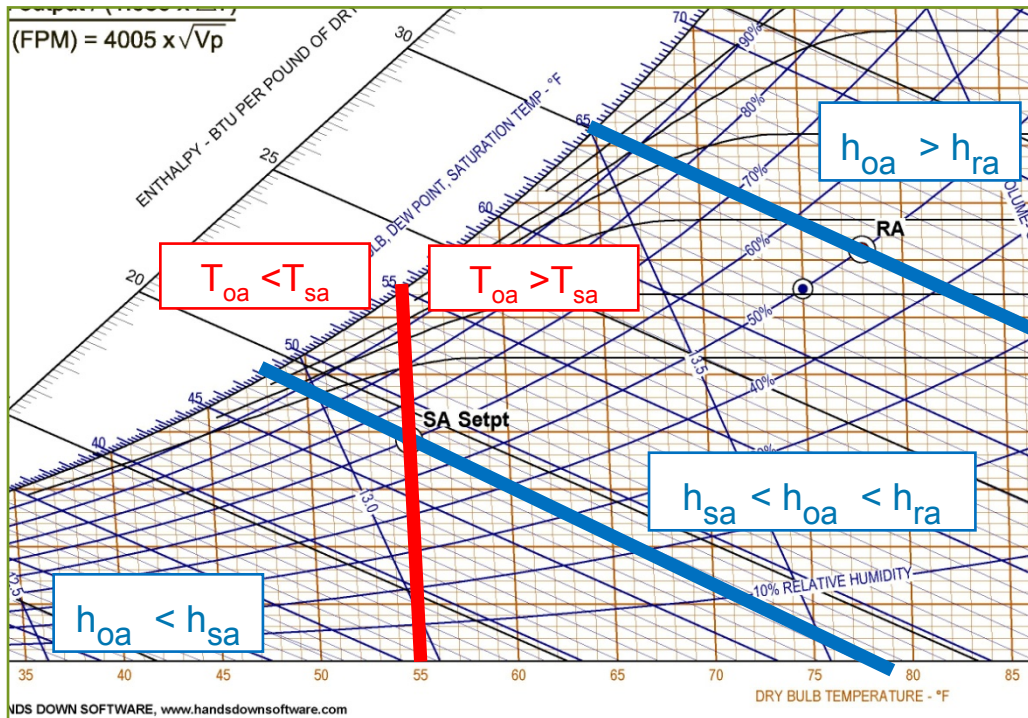
1. The economizer shall be enabled whenever:

- The outside air enthalpy is less than the return air enthalpy, measured downstream of the return fan.
- AND the fan status is on.

2. When the Outdoor Air enthalpy is greater than the supply air enthalpy set point, the outdoor air damper(s) shall be set for 100% outdoor air

3. When the Outdoor Air temperature is less than the supply air temperature set point, the outdoor air damper, exhaust air damper, and return air damper will modulate, as appropriate, between the adjustable minimum position and full open to maintain the Discharge Air Temperature that will meet the room thermostat demand.

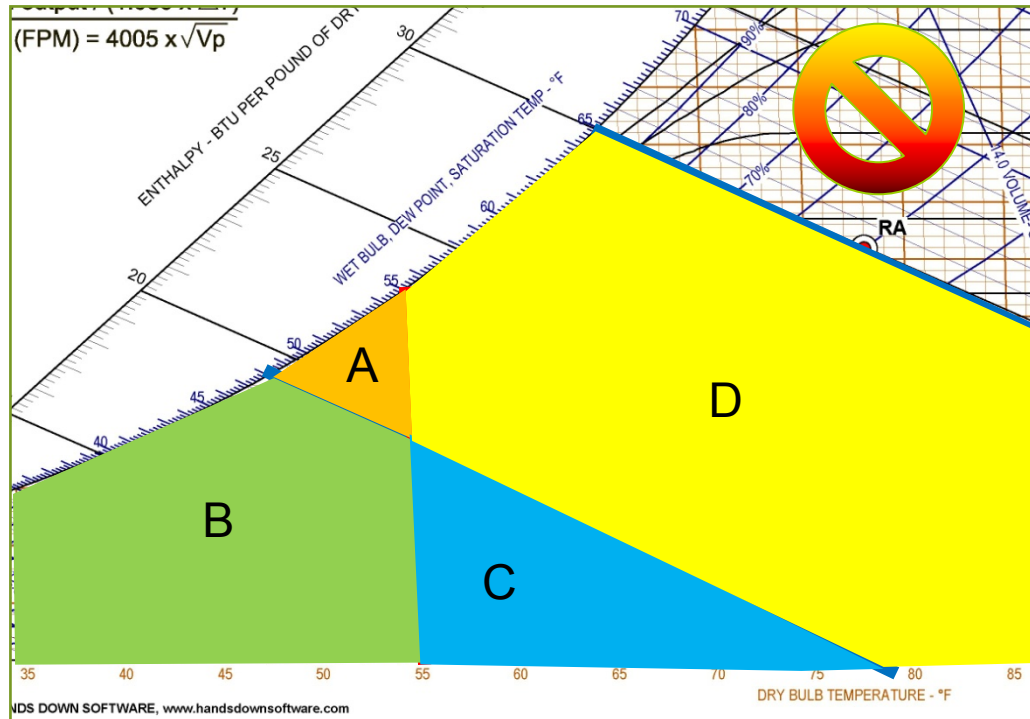
4. When the return air enthalpy is less than the outside air enthalpy the exhaust air damper, return air damper, outside air damper shall be positioned to the minimum outside air position.



Sequence as Published

1. The economizer shall be enabled whenever:

- The outside air enthalpy is less than the return air enthalpy, measured downstream of the return fan.
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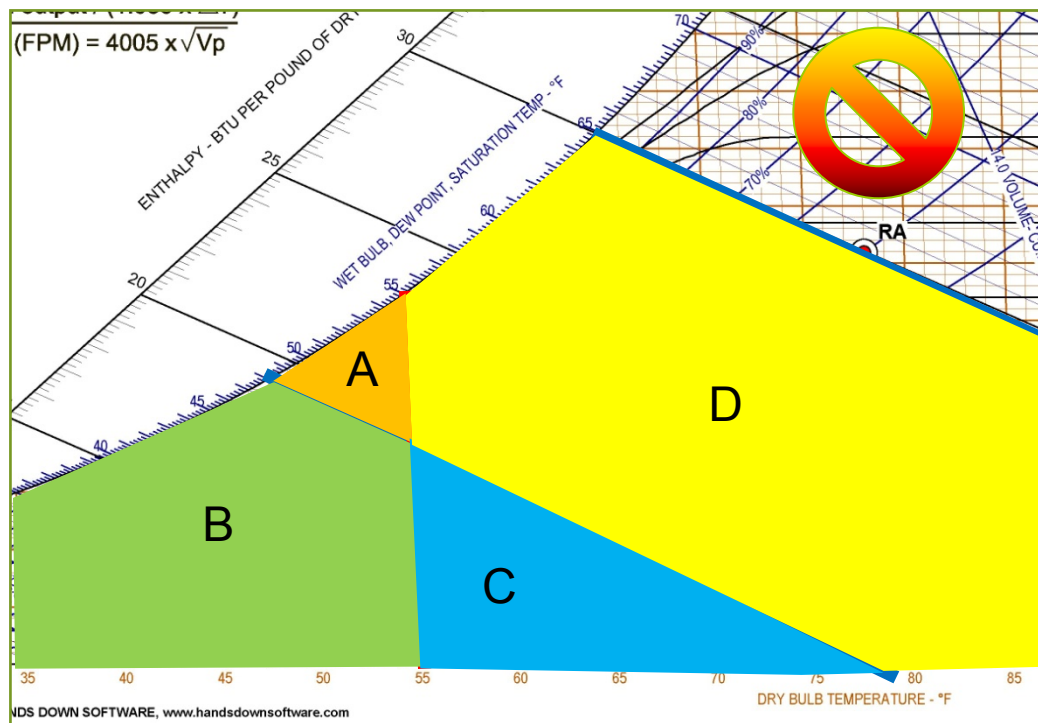


2. When the Outdoor Air enthalpy is greater than the supply air enthalpy set point, the outdoor air damper(s) shall be set for 100% outdoor air
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Suggested Sequence Correction

1. The economizer shall be enabled whenever:

- The outside air enthalpy is less than the return air enthalpy, measured downstream of the return fan.
- AND the fan status is on.



2. When the Outdoor Air enthalpy is greater than the supply air enthalpy set point, AND the Outside air temperature is greater than the supply air temperature set point (D), the outdoor air damper(s) shall be set for 100% outdoor air.
3. When the Outdoor Air temperature is less than the supply air temperature set point OR the Outdoor air enthalpy is less than the Supply air enthalpy set point (A,B & C) the outdoor air damper, exhaust air damper, and return air damper will modulate, as appropriate, between the adjustable minimum position and full open to maintain the Discharge Air Temperature that will meet the room thermostat demand.
4. When the return air enthalpy is less than the outside air enthalpy the exhaust air damper, return air damper, outside air damper shall be positioned to the minimum outside air position.



Final Sequence

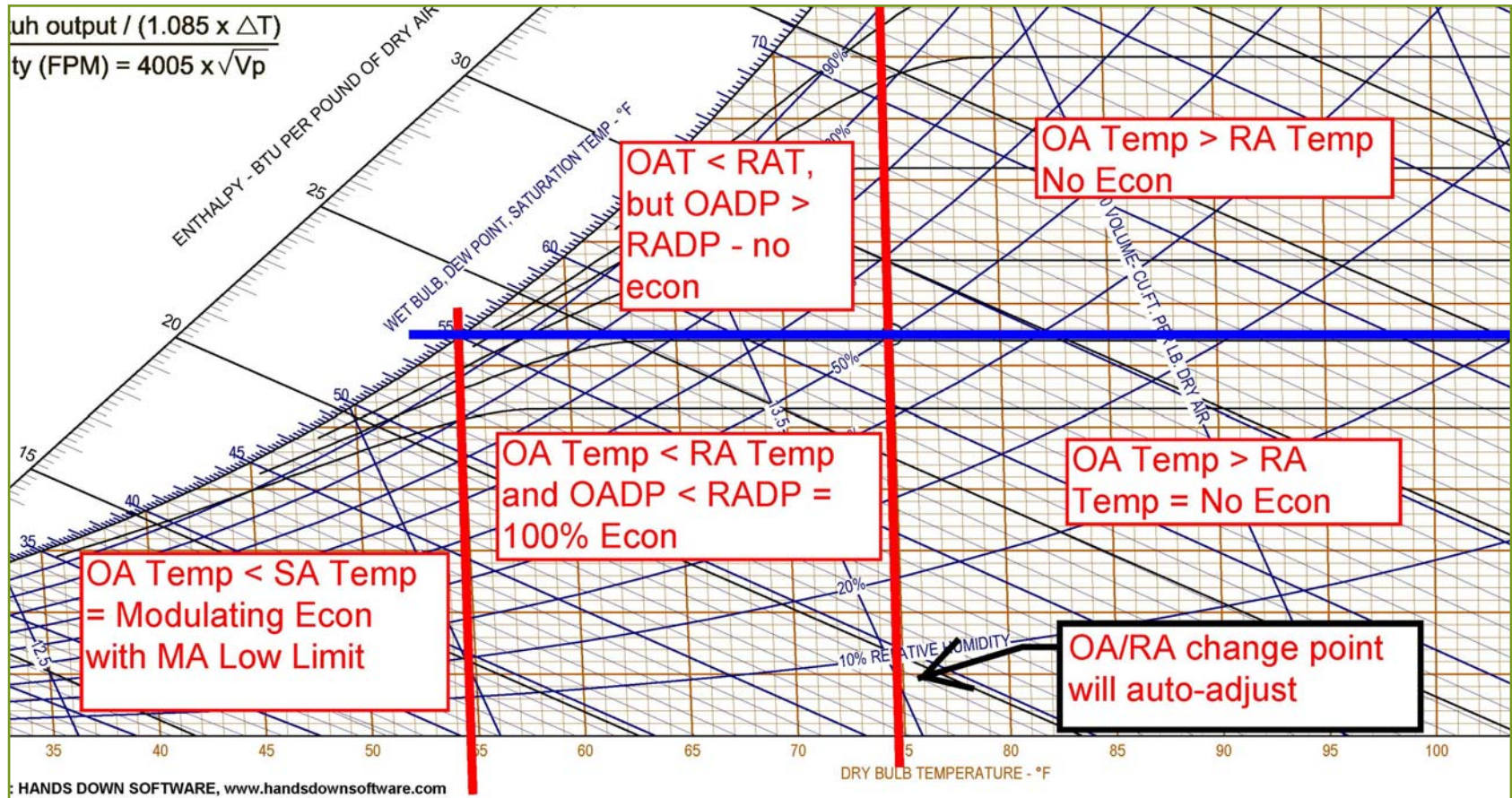
1. The economizer shall be enabled whenever:
 - a. The outside air dry-bulb temperature is less than the return air dry-bulb temperature
 - b. AND the fan status is on.
2. When the outside air dew point is less than the return air dew point by an adjustable dead band (3 deg F), the outdoor air damper(s) shall be set for 100% outdoor air
3. When the Outdoor Air temperature is less than the supply air temperature set point the outdoor air damper, exhaust air damper, and return air damper will modulate, as appropriate, between the adjustable minimum position and full open to maintain the Discharge Air Temperature that will meet the room thermostat demand.
4. When the return air dew point is greater than the outdoor air dew point OR the outdoor air temperature is greater than the return air temperature the exhaust air damper, return air damper and outside air damper shall be positioned to the minimum outside air position.

Final Sequence – continued

5. The economizer shall close to 0% (outside air and exhaust dampers shall be closed and return air damper shall be open) whenever:
 - a. Supply fan or return fan is off
 - b. OR mixed air temperature is less than 40°F (1).
 - c. OR on loss of fan status.
 - d. OR the Discharge Air Temperature Sensor has failed
 - e. OR the AHU is in the Morning Warm-up or Cool-down mode
6. The Outdoor Air Damper shall be set to its adjustable minimum position if the Economizer function is disabled. Maintain minimum outside air by modulating the outside air damper to maintain a pre-measured static pressure differential, measured immediately at the discharge of outside air damper, and with reference to outdoors.
7. Alarms shall be provided as follows:
 - a. High Mixed Air Temp: If the mixed air temperature is 5°F greater than set point.
 - b. Low Mixed Air Temp: If the mixed air temperature is 5°F less than set point.
 - c. High or low supply air temperature

Final Sequence

Psychrometric Chart





Text Presentation

1.Boiler Operation

A. The boiler plant shall be enabled to run whenever:

- a. The boiler plant is scheduled on and a definable number of hot water coils need heating,
- b. OR the outside air is below 60 degrees F and any zone is in the heating or warm-up mode as indicated by

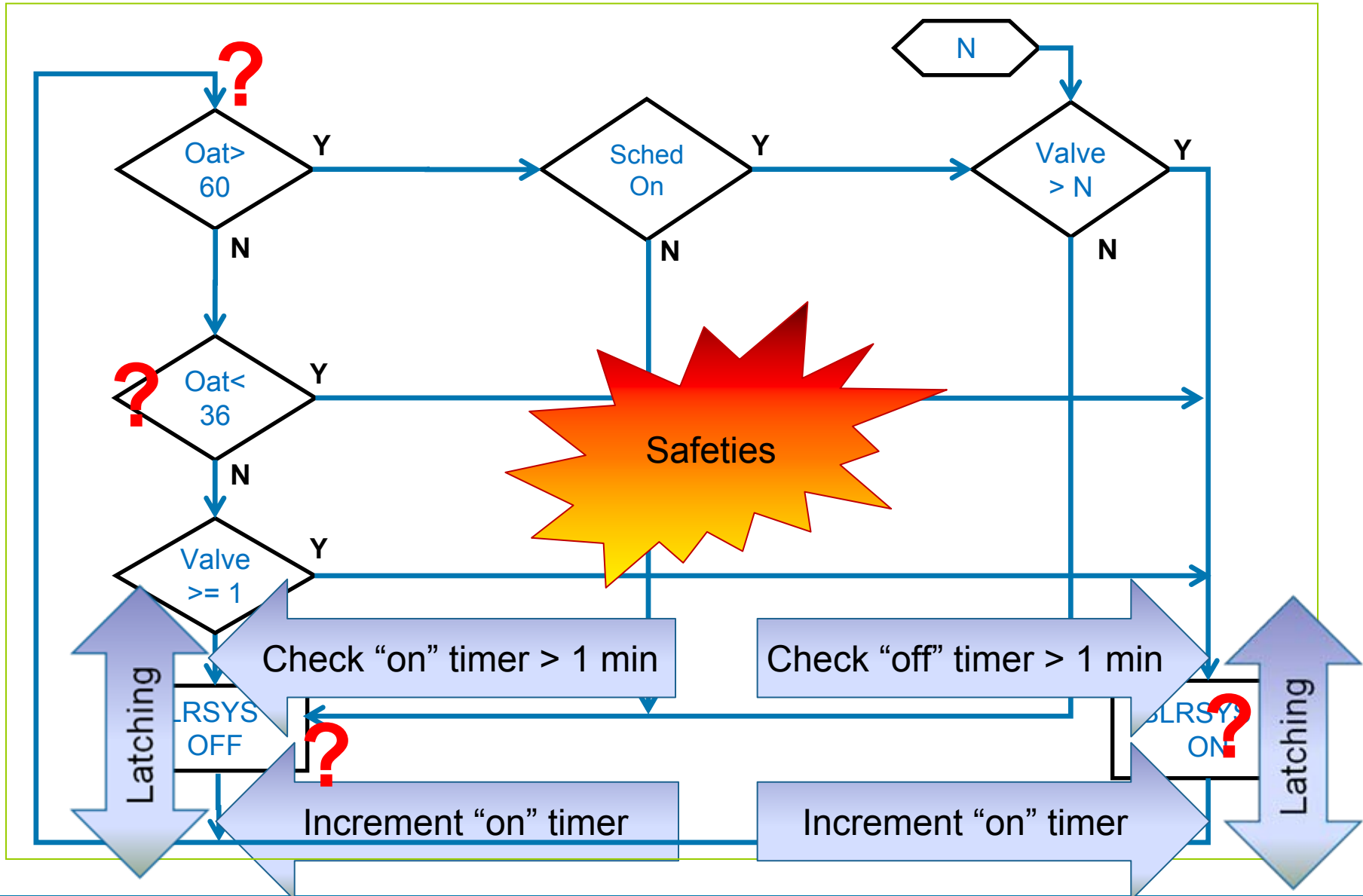
at least one single heating valve modulating open,

- c. OR the outside air temperature is below 36 degrees F.

B. To prevent short cycling, the boiler system shall run for a minimum of 1min (adj.) and be off for a minimum of 5 min (adj.), unless shut down on safeties or outside air conditions.

C. The lag boiler shall be....

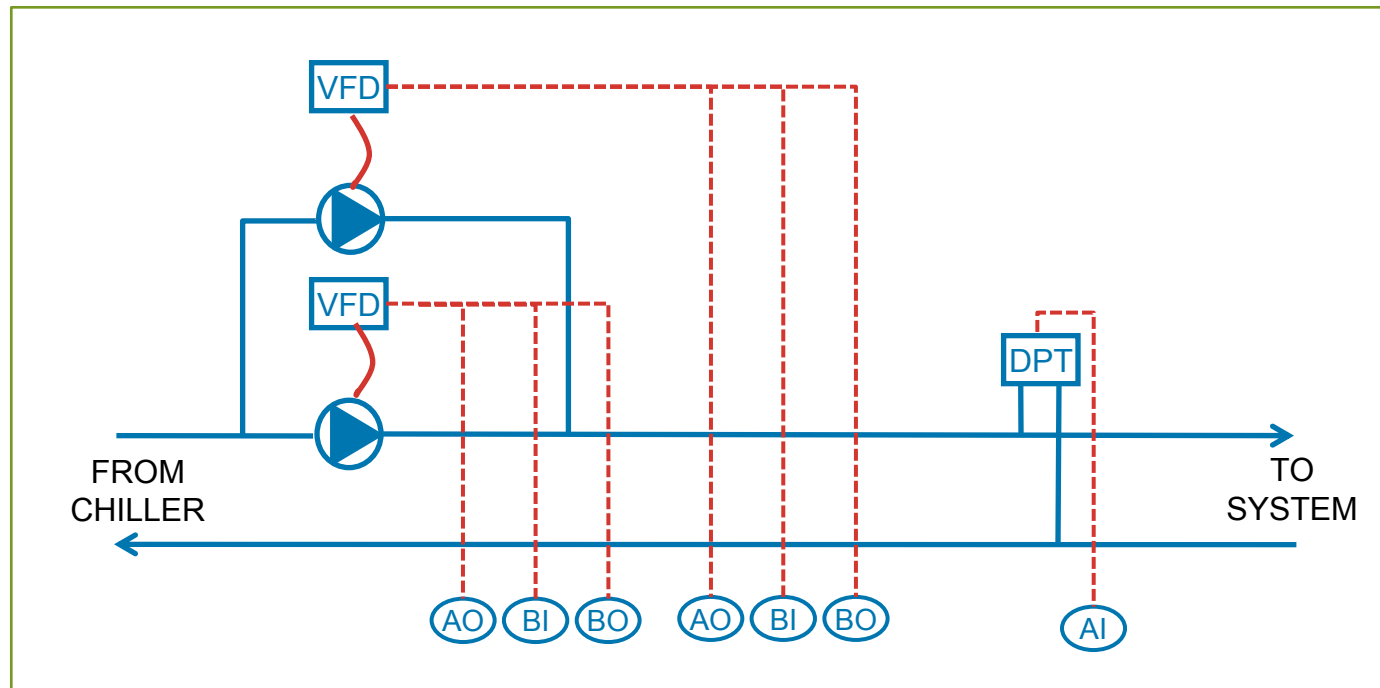
Graphical Presentation



Industry Standard Controls

Differential Pressure Control of Pump Speed

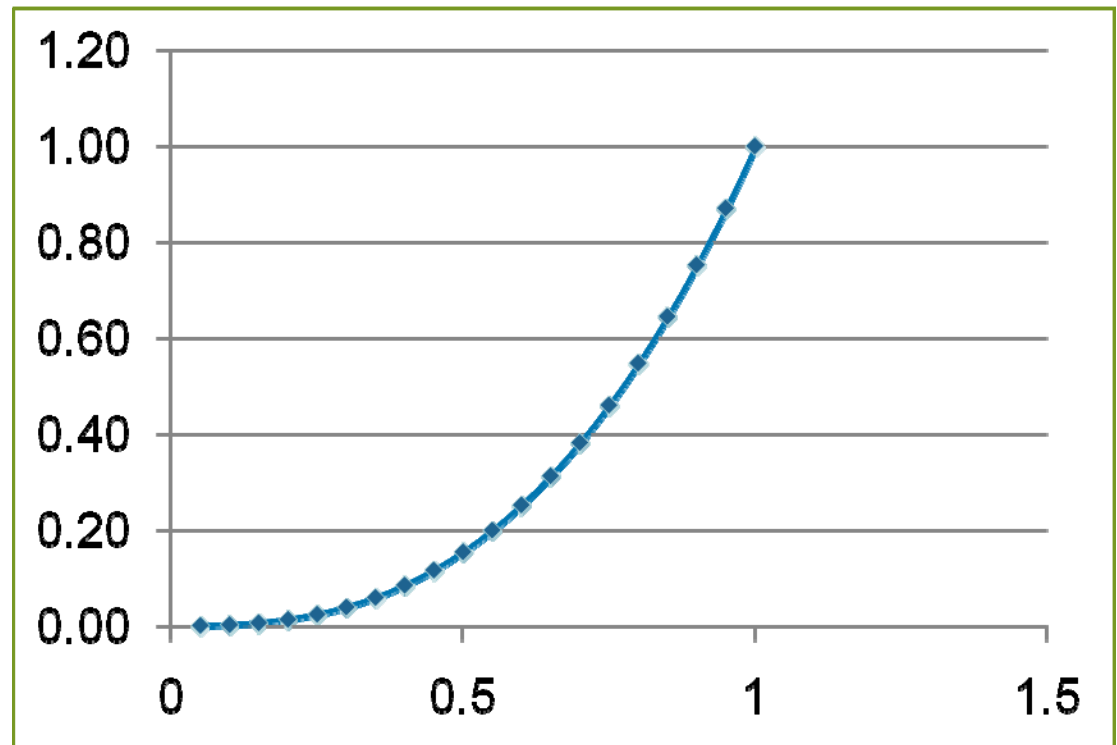
- Fixed DP setpoint is established during system balancing to provide full system flow.
- One or two VFDs modulate the speed to maintain the DP setpoint during operation.



High Performance Controls

Valve Orifice Area Control of Pump Speed

- Fractional valve opening is calculated by raising the fractional valve actuator position to the 2.7 power
- Multiply the fractional valve opening by the valve's full flow.
- Sum the flows to create a system flow requirement
- Compare to the full system flow to send a fractional speed requirement to the pump drive





Industry Standard vs. High-Performance

Things to look for:

- The “usual” Sequence Troubles
- Equipment / Integrated Controls
- “Contractor Inertia”



Controls Integration Meetings

Purpose:

- “to review the intended programming and controls installation against the designers’ sequence of operation and the BOD/OPR to have absolute clarity *before* too much effort and cost is expended in the field.”



Functional Testing

Last Line of Defense

- If the CIM didn't catch it...
- Keep Schedule from overriding Quality
- **All** modes of operation are tested.
- The “Most Expert” team is available for troubleshooting.



Project Turnover

Preserving “Intellectual Capital”

- Written Documentation – O & M, As Builts, TAB Reports, Cx Final Report.
- Operator Training
 - Multiple Short Sessions
 - Education Tracks
 - Hands-On Training
 - What-if Training
 - Learning to use the tools



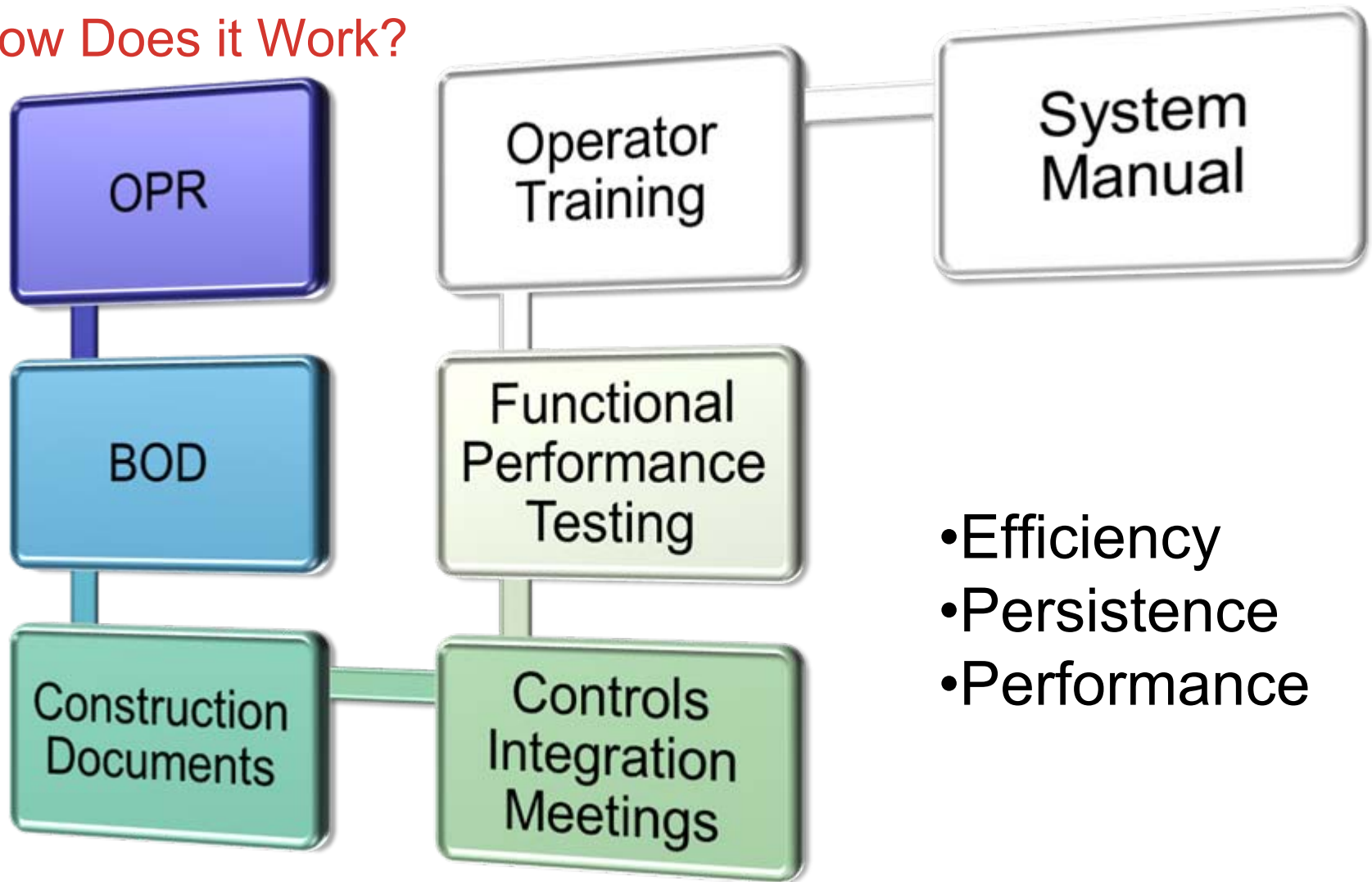
The Systems Manual

Consider the goal –

- Technical manual vs. Owner's manual
 - Distill the technical details into easy-access for day-to-day operations & maintenance.
 - Simplify the language
 - Remove “trade language”
 - Consider the expected reader

Sequence of Operation

How Does it Work?



- Efficiency
- Persistence
- Performance

AIA Quality Assurance



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Thank You

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Pump Curve for DP control

