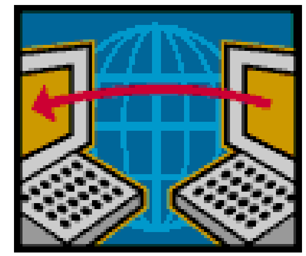
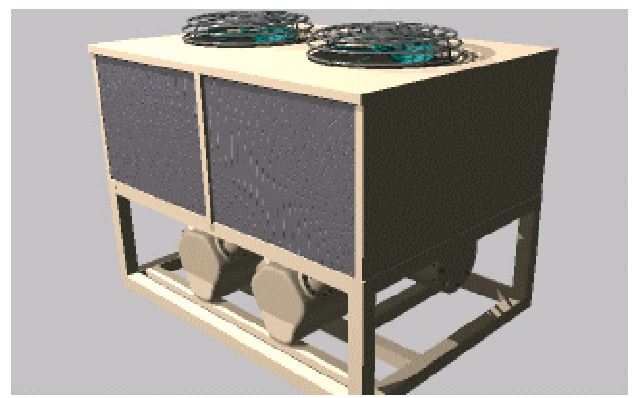
# DDC
# Control Fundamentals
# and Energy Conservation
# for
# HVAC Equipment-Part 2



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# DDC Controls and Energy Conservation for HVAC Equipment –Part 2- Agenda

1. DDC Control Applications
2. DDC Networks and Architecture
3. Communication Standards for DDC Controls
4. Vendor Examples of DDC Software Programming and Operator Interfacing
5. Understanding the Sequence of Operations
6. System Maintenance and Service of DDC Controls
7. Using DDC Controls to Save Energy

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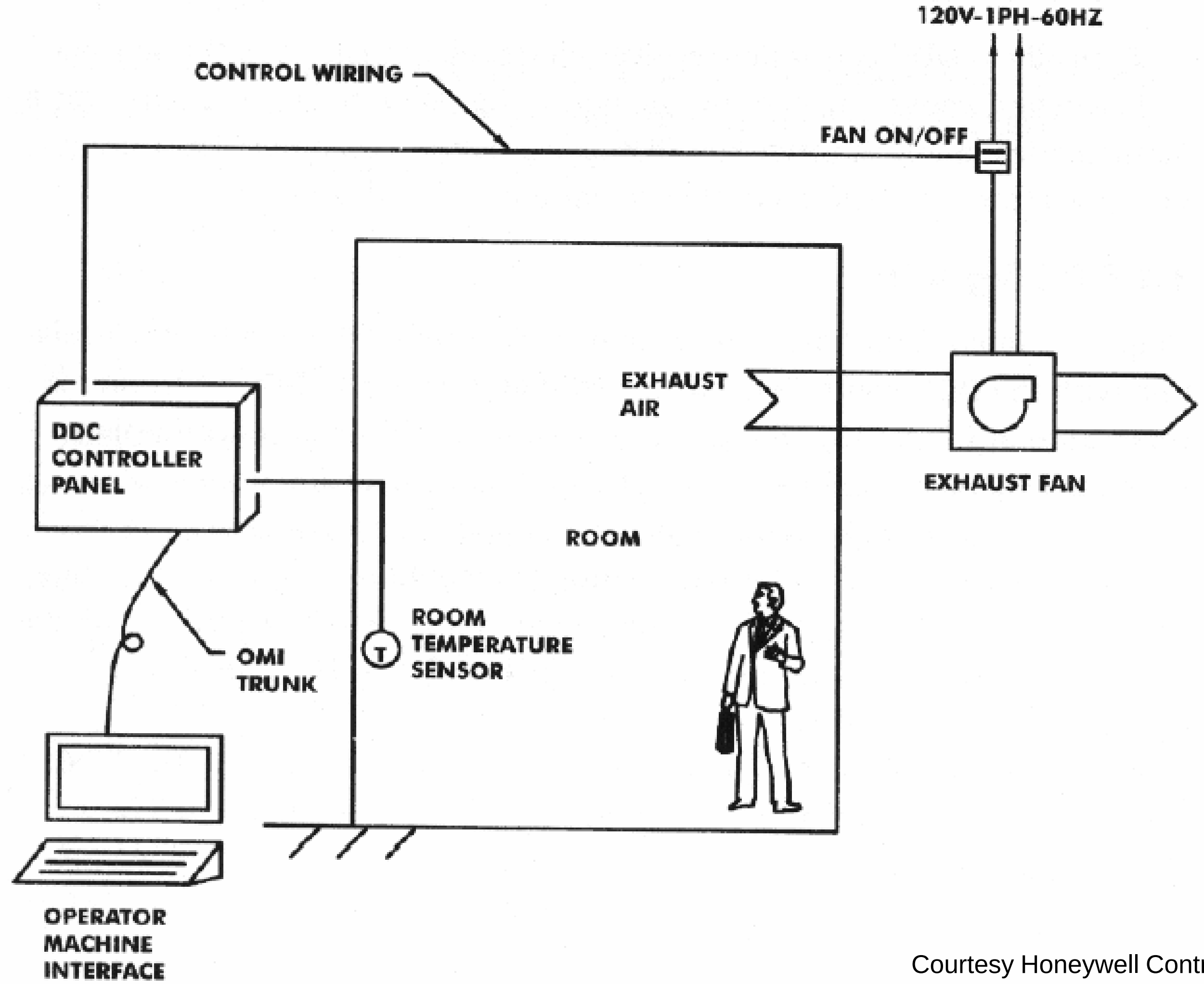
# Section 1
# DDC Control Applications

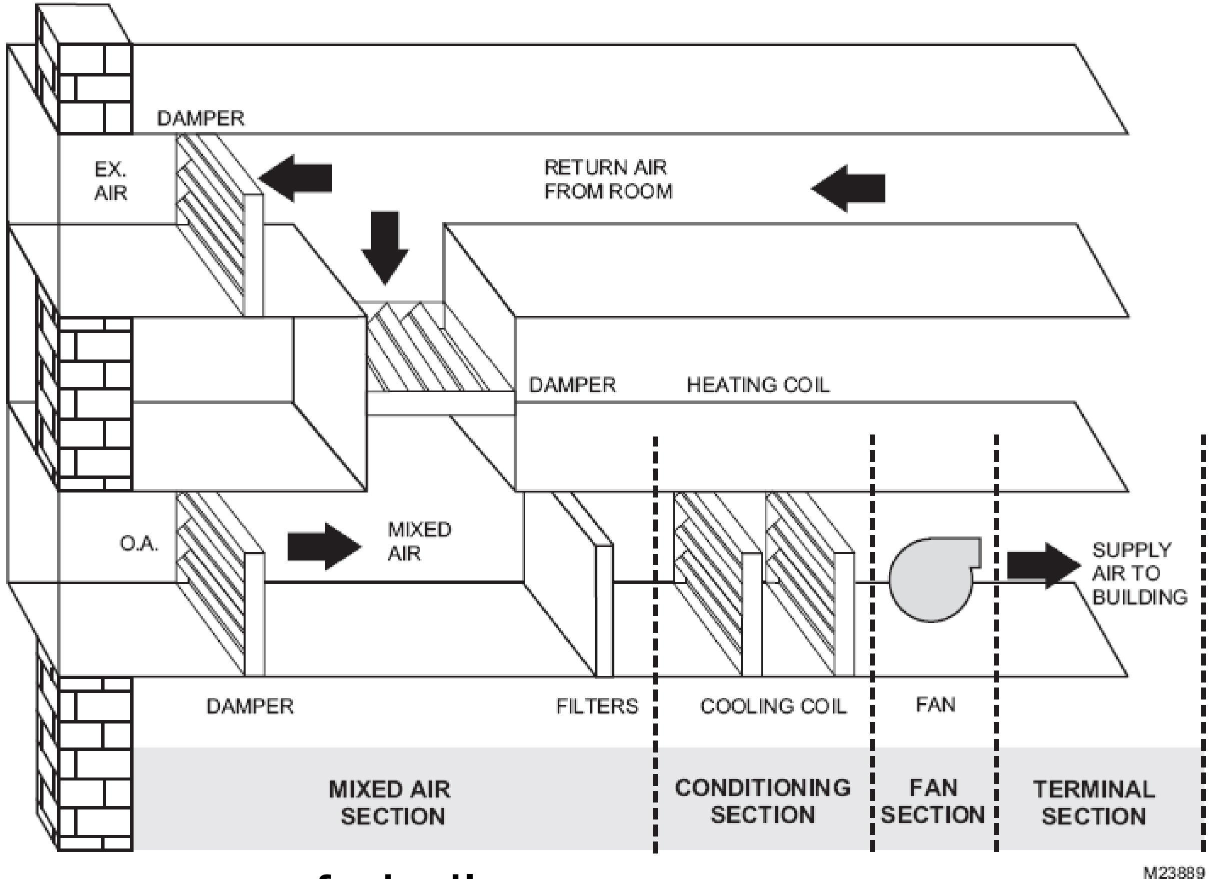
- Room Exhaust Basic Control
- Air Handler Controls
  - Constant volume-single zone
  - Multi-zone
  - Dual duct
  - Variable air volume- VAV
- Heating Systems with OSA Reset
- Energy Management Techniques for Various AHU Fan Systems

# DDC Application for a Room Exhaust Control System




Courtesy Honeywell Controls

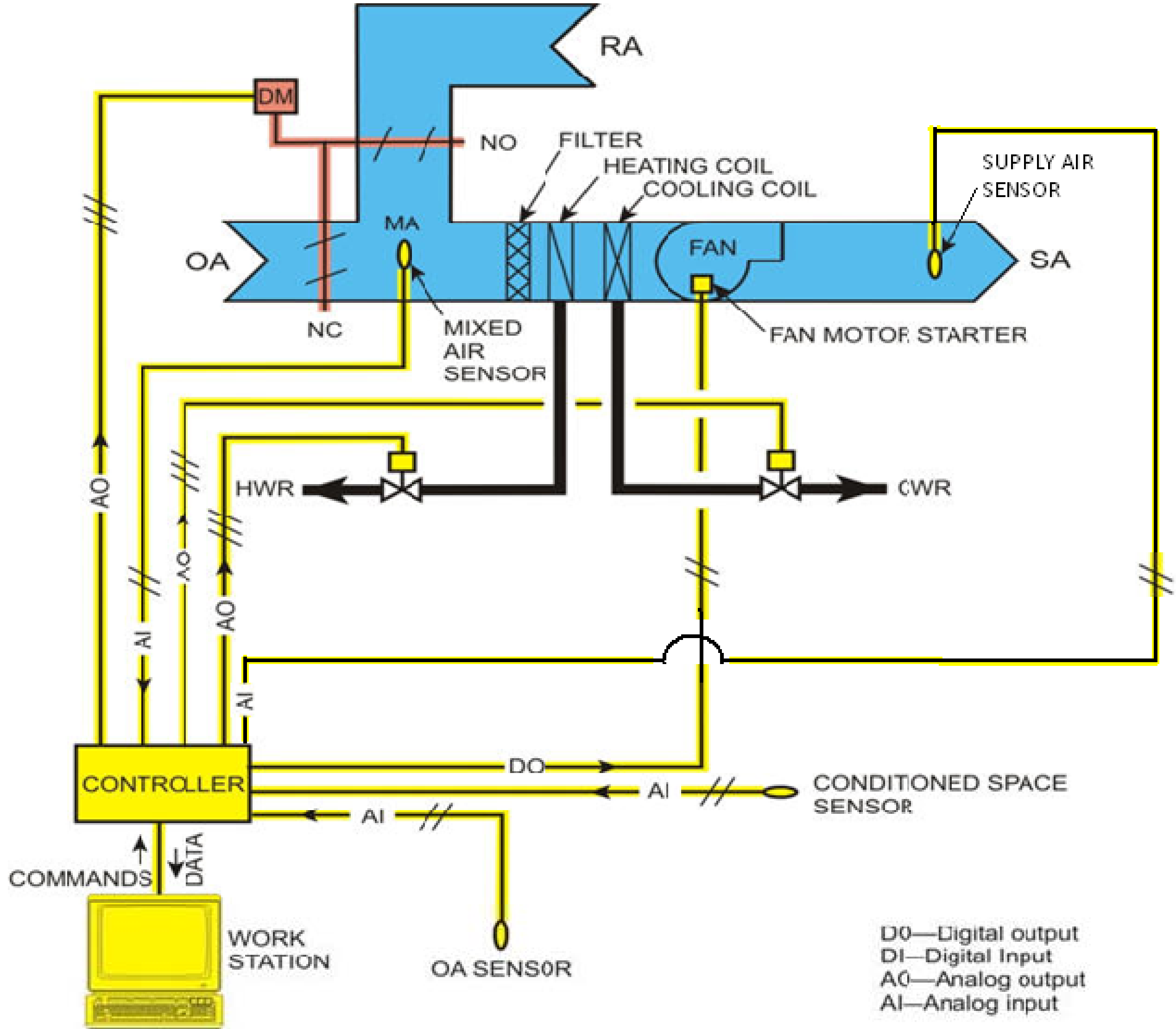
# Single Zone Air Handler Control Basics




- Controls temperature of similar zones
- Can utilize economizer, heating coils, cooling coils
- Efficiency is increased based on zone requirements

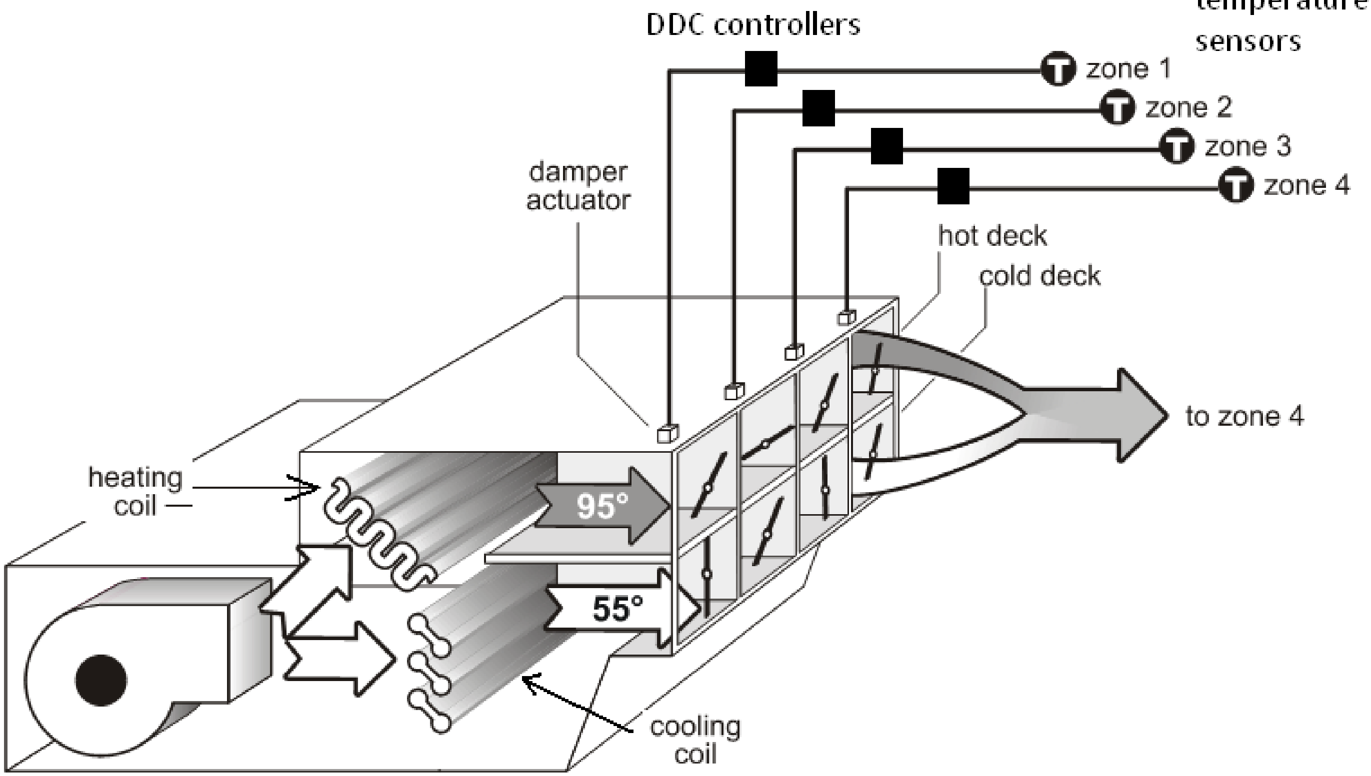
Courtesy Honeywell Controls

# Single Zone AHU Control Application with DDC Controller




Courtesy LAMA Books

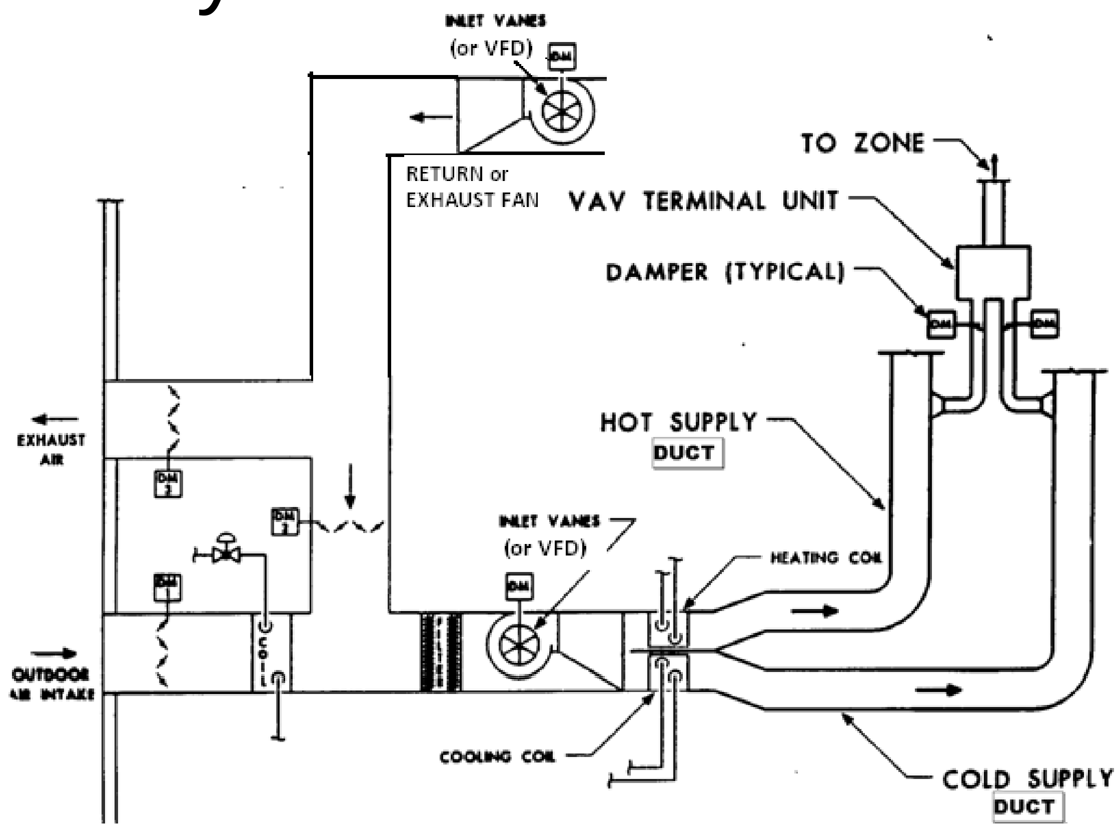
# Multi-Zone AHUs




- Air is blown over coils at the air handler in parallel
- Each zone thermostat controls a pair of interconnected dampers which mix the air
- Efficiency increases when discharge air temperatures is reset on zone requirements
- Reset hot and cold deck temperatures based on temperature sensor signals from the zones

Courtesy Northwest Energy Efficiency Council

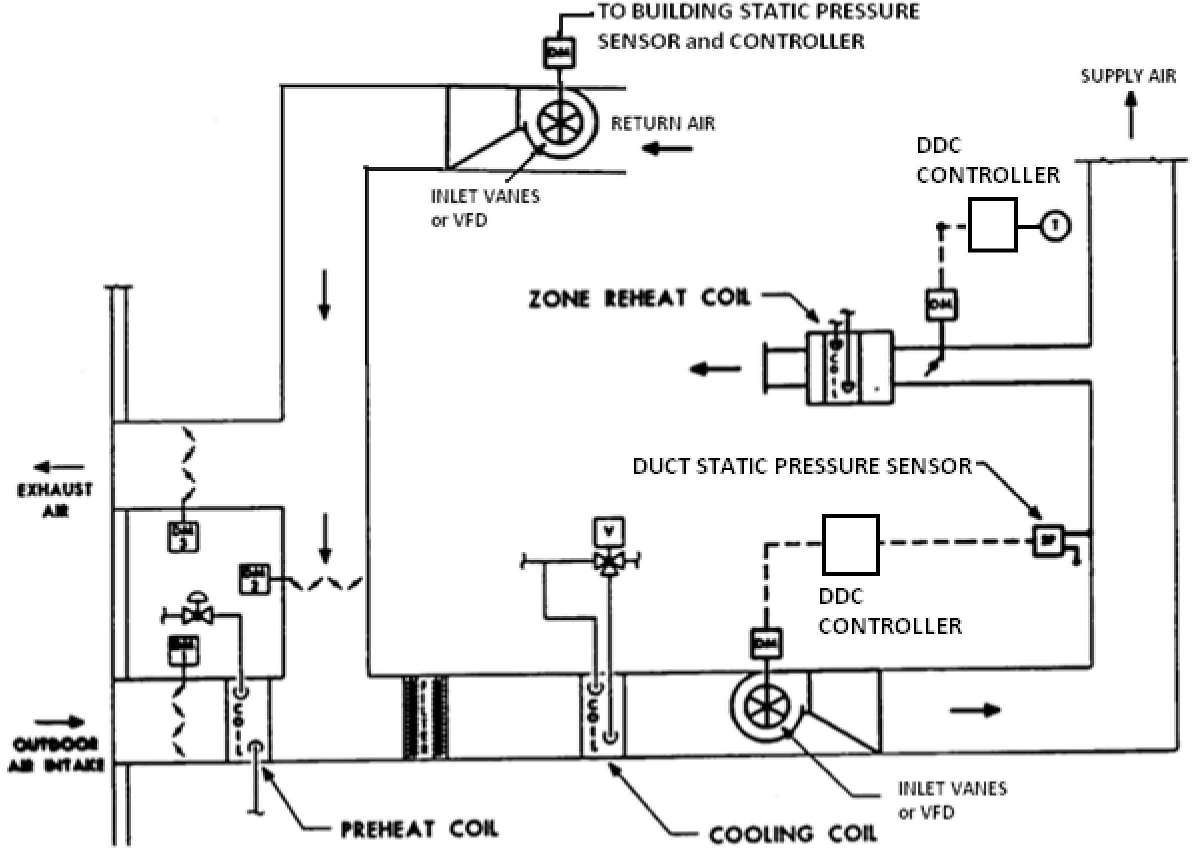
# Dual Ducted System




- Similar to multi-zone AHU, except air is mixed in the zone
- Temperature blended hot/cold air
- Mixing box near each zone
- Damper linkages must be adjusted
- Efficiency based on temperature signals from zones

Courtesy Northwest Energy Efficiency Council

# Variable Air Volume With Reheat




- VAV systems vary the air supplied to each zone depending on the load, saving fan energy.
- VAV systems typically use cooling only air handlers.
- Volume of air delivered is varied using inlet dampers or electronic speed controls based on supply duct static pressure setpoint.

Courtesy Northwest Energy Efficiency Council

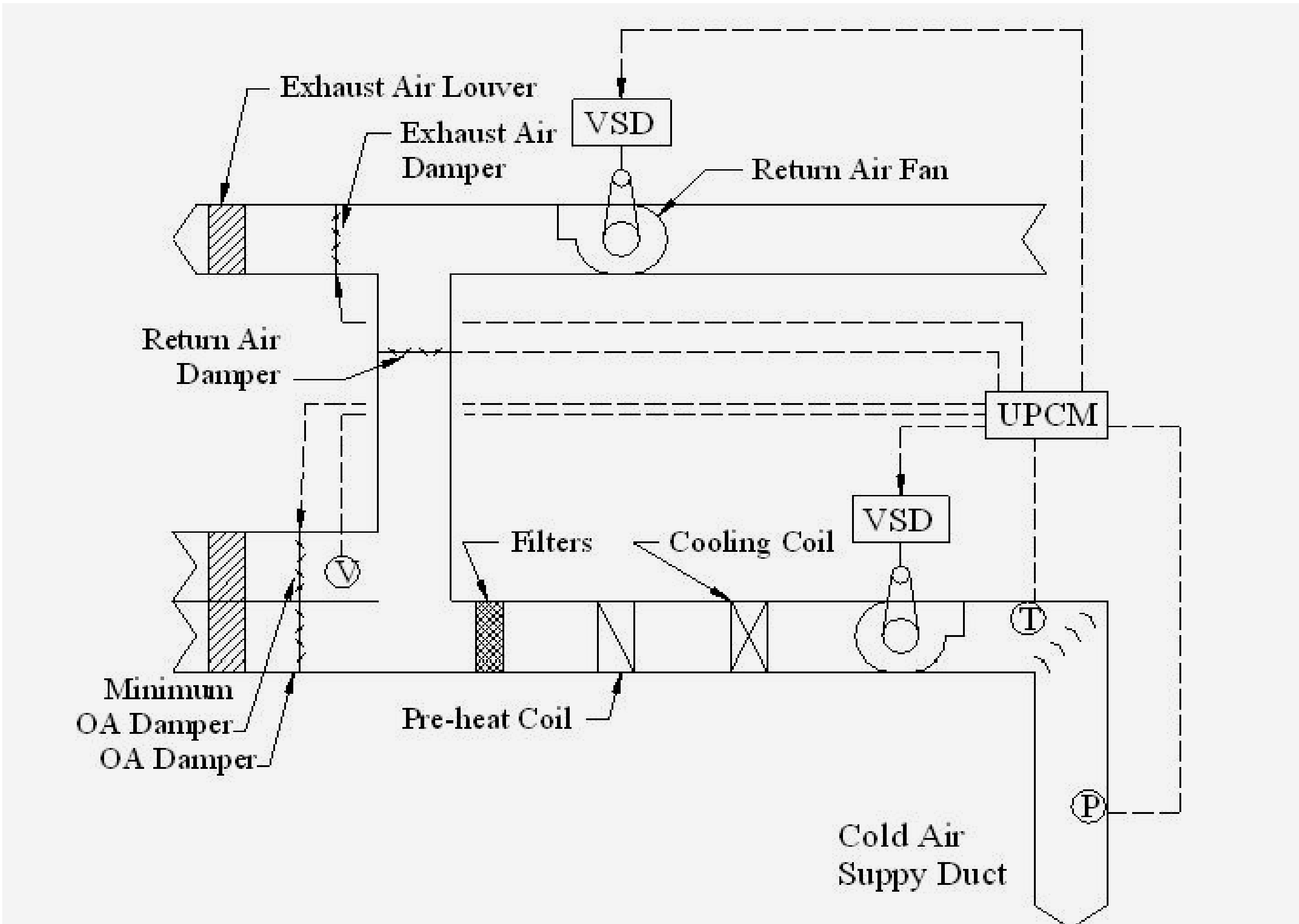
# Energy Management Techniques

## Various AHU Fan Systems

- Single Zone/Constant Volume Systems
  - Reset discharge air temperatures and mixed air temps based on zone requirements.
- Multi-Zone and Dual Duct Systems
  - Reset hot and cold deck temps based on zone loads & temperatures.
- Variable Air Volume (VAV)
  - Use electronic VSD at the fan motor; supply and return fans should track together. Use PI or PID to create fan stability.
- General Energy Saving Techniques for AHUs
  - Operate zones based on load and occupancy needs.
  - Set start and stop times to anticipate increasing and declining loads, based on inside and outside temperatures.
  - Schedule the static pressure setpoint to drop after normal occupancy hours, or during low load conditions.
  - Disable the mechanical cooling coil and pumps when outside air temperatures drop below 60 deg F.

# Many Factory Built-Up AHUs

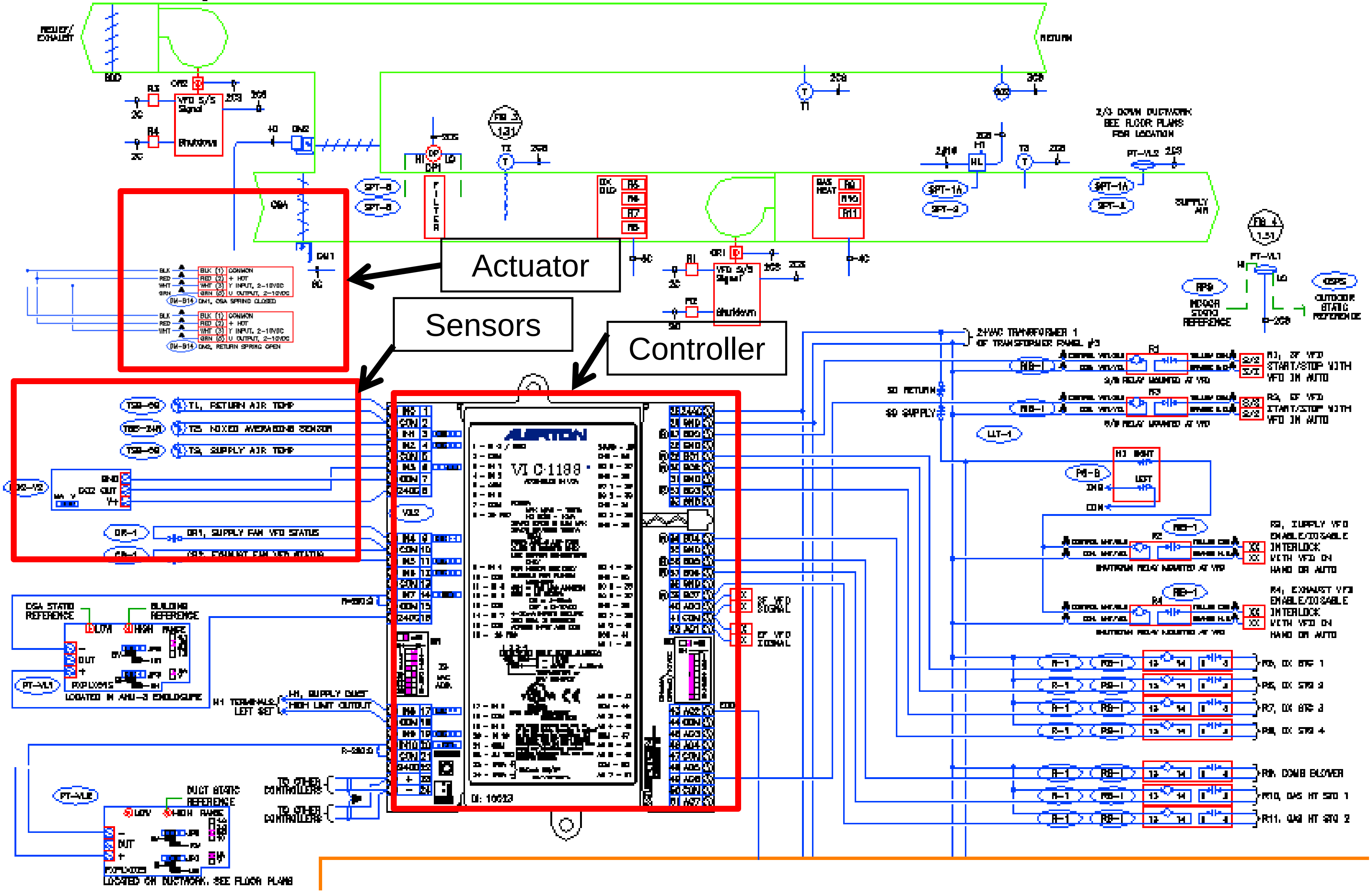
## Are Variable Air Volume (VAV) with DDC Controls




Source http://www.mmtmagazine.org/page/indexa916.html?id=44

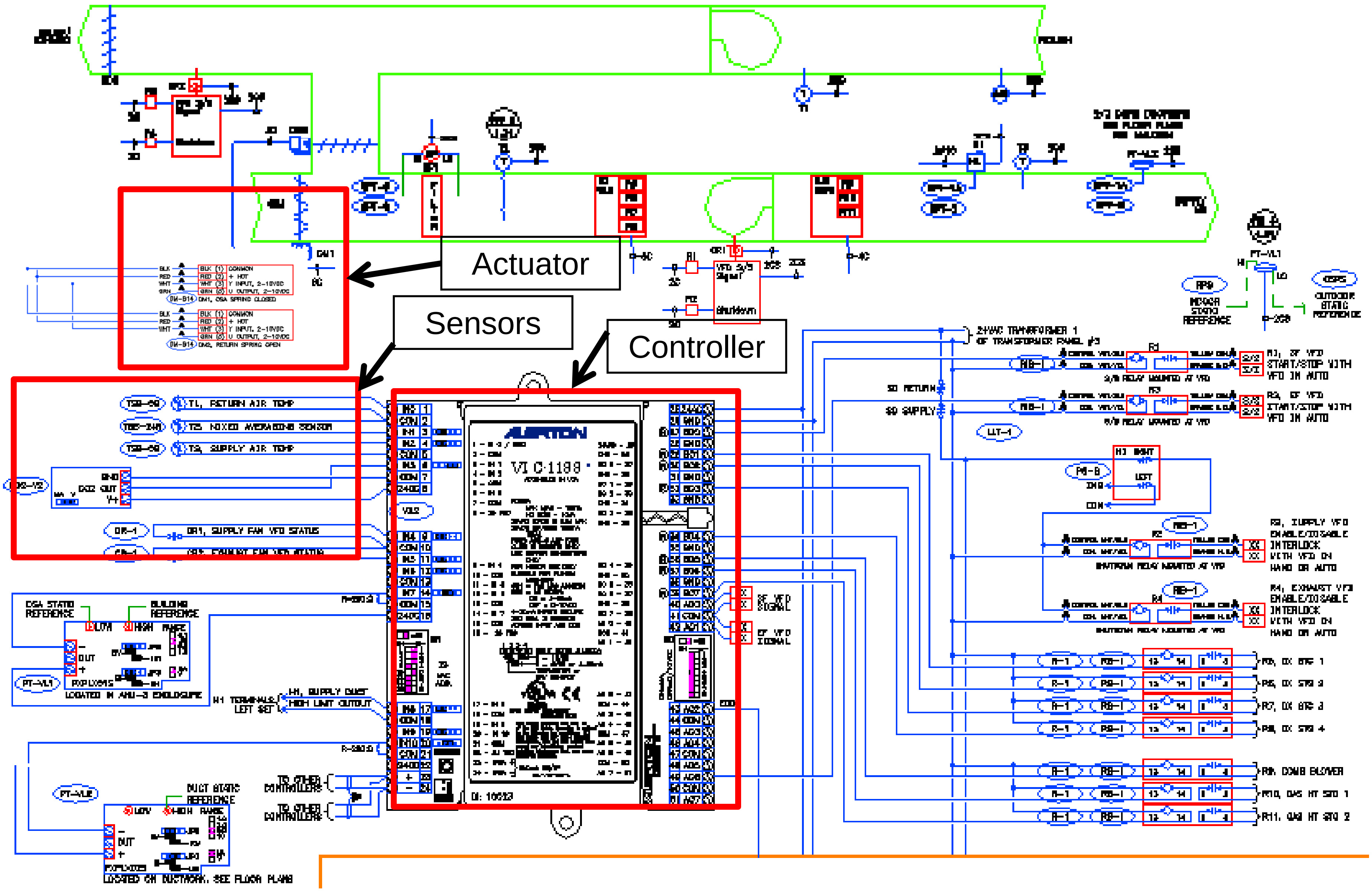
# Typical Controls on Factory AHUs

## Example of Schematic for Alerton Controls



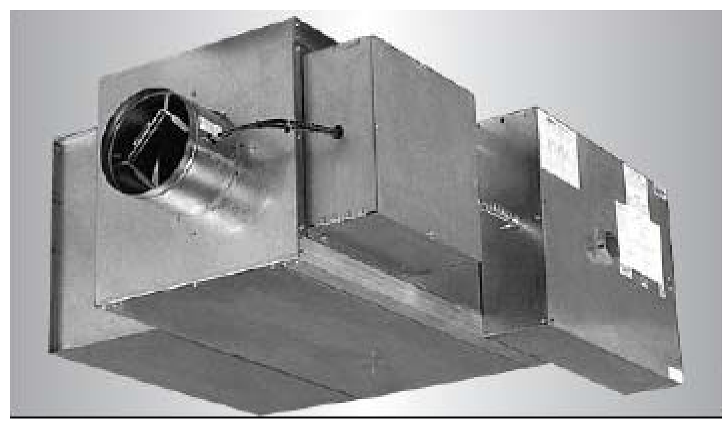
# Typical Controls on Factory AHUs

## Example of Schematic for Alerton Controls



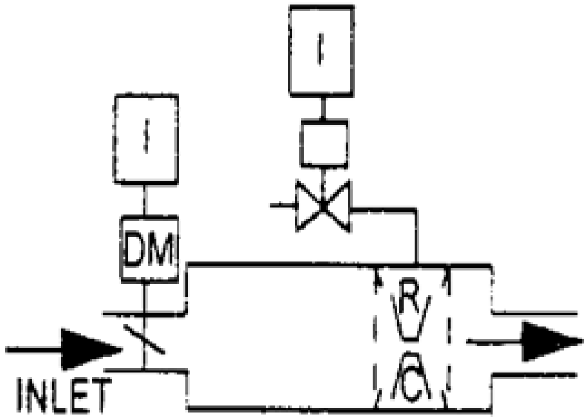
# Throttling VAV Terminal Units

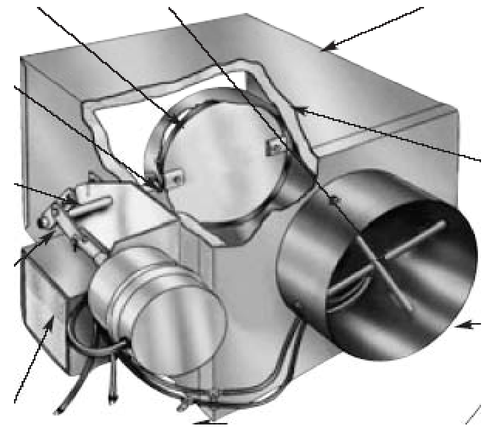
- Damper inlet controls supply air between a min/max flow rate
- Includes a reheat coil and control valve
- Provide air to appropriate zones
- Min setpoint provides enough fresh air



Courtesy Nailor Industries

# Throttling VAV Terminal Unit



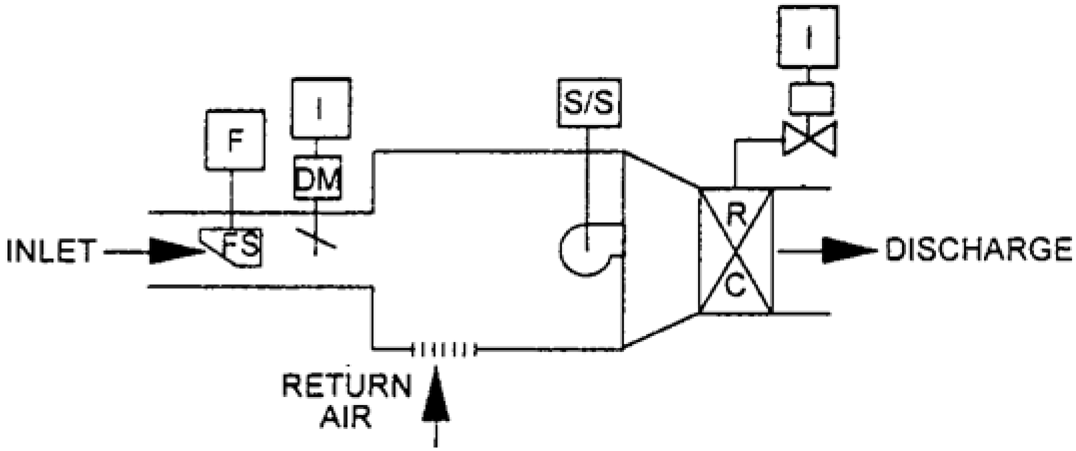



Components within the VAV box include:

- Room Thermostat or Sensor
- Velocity Sensor
- Controller
- Damper Actuator

Courtesy Northwest Energy Efficiency Council

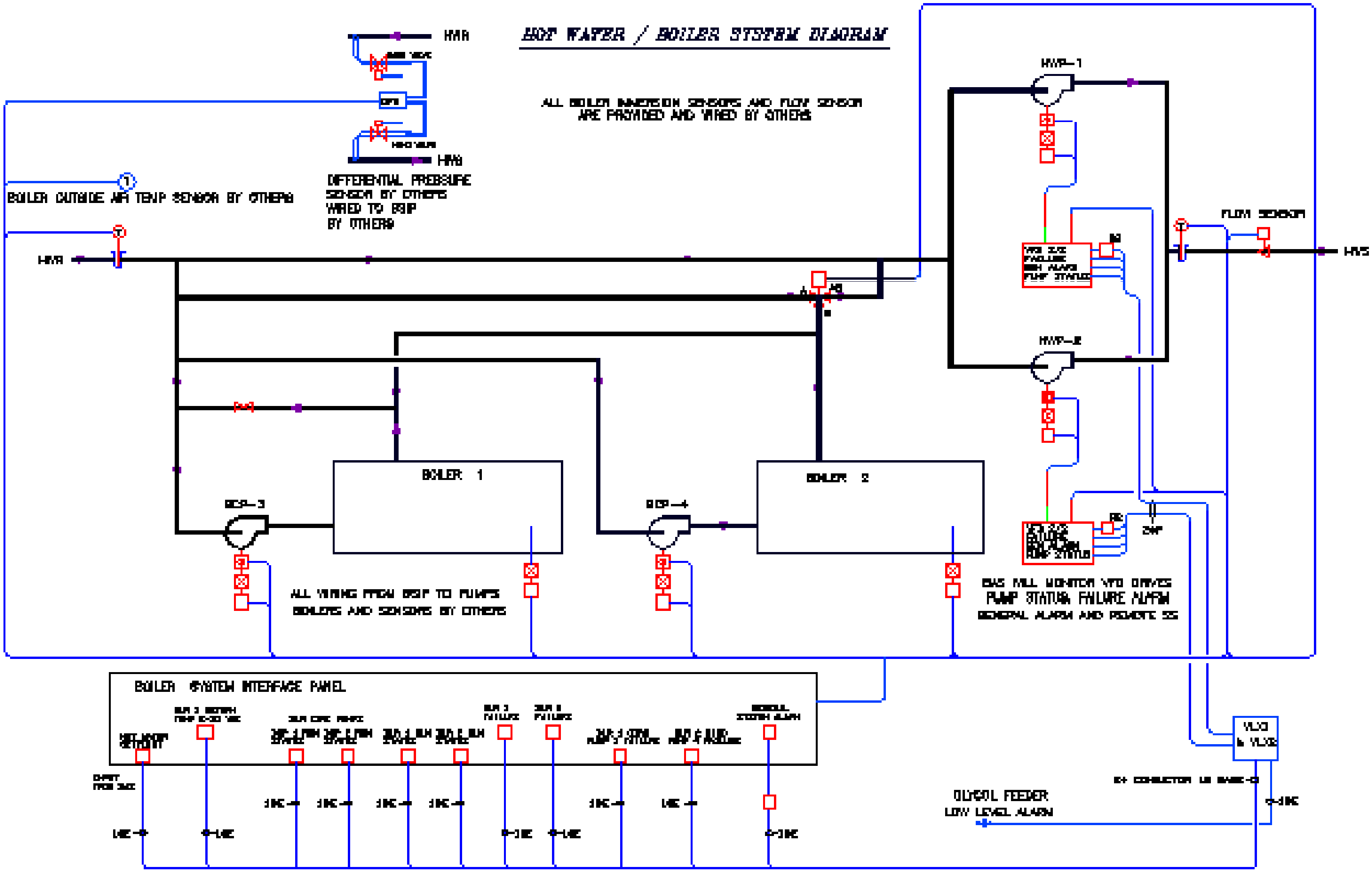
# Fan Powered VAV Terminal Unit



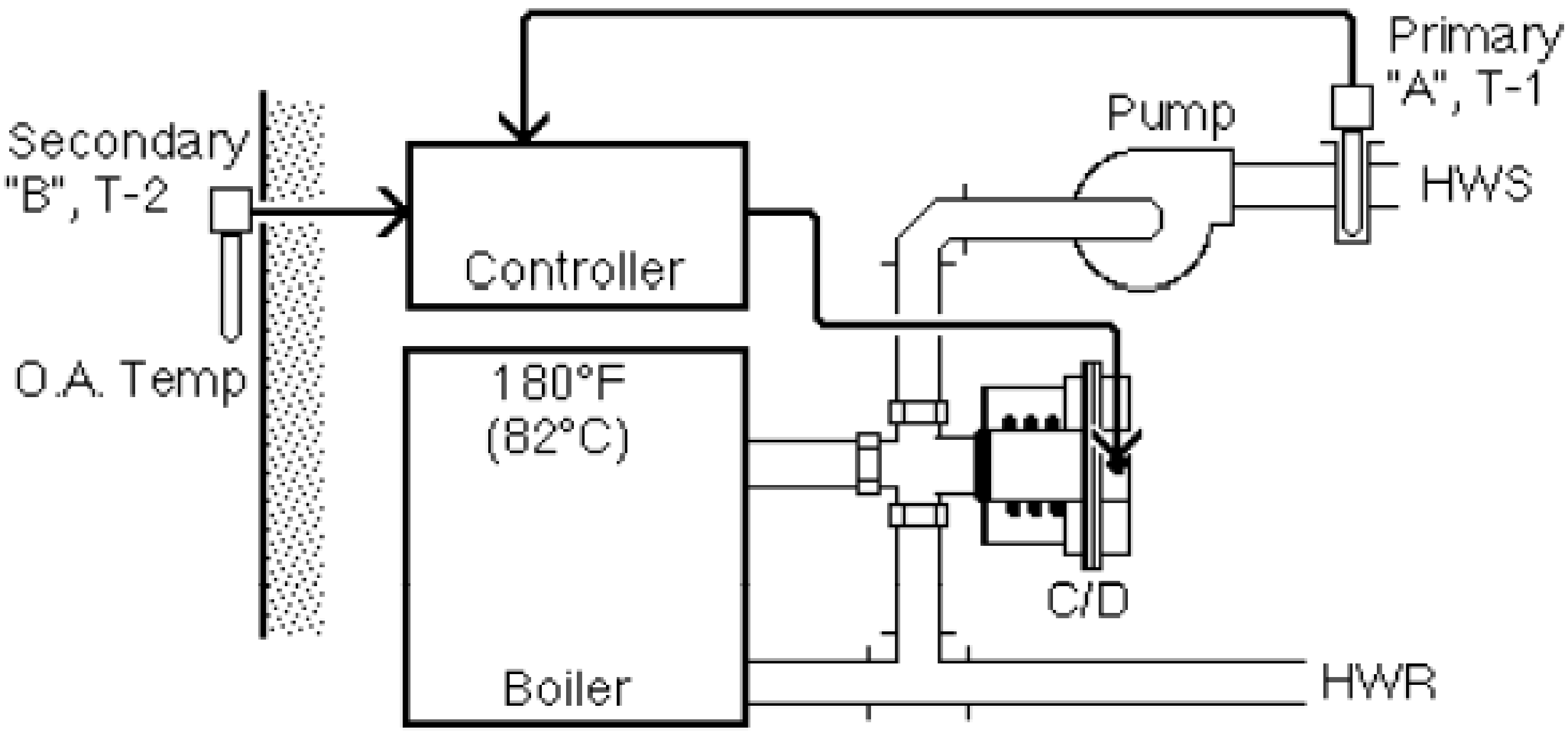

- Fan provides constant volume
- Intermittent fan units
- Supply damper modulates min and max
- Reheat coil added to maintain min temp
- Fan runs as needed to maintain temperature

Courtesy Northwest Energy Efficiency Council

# Example of DDC Boiler Heating Controls Schematic



# Boiler Control With OSA Reset

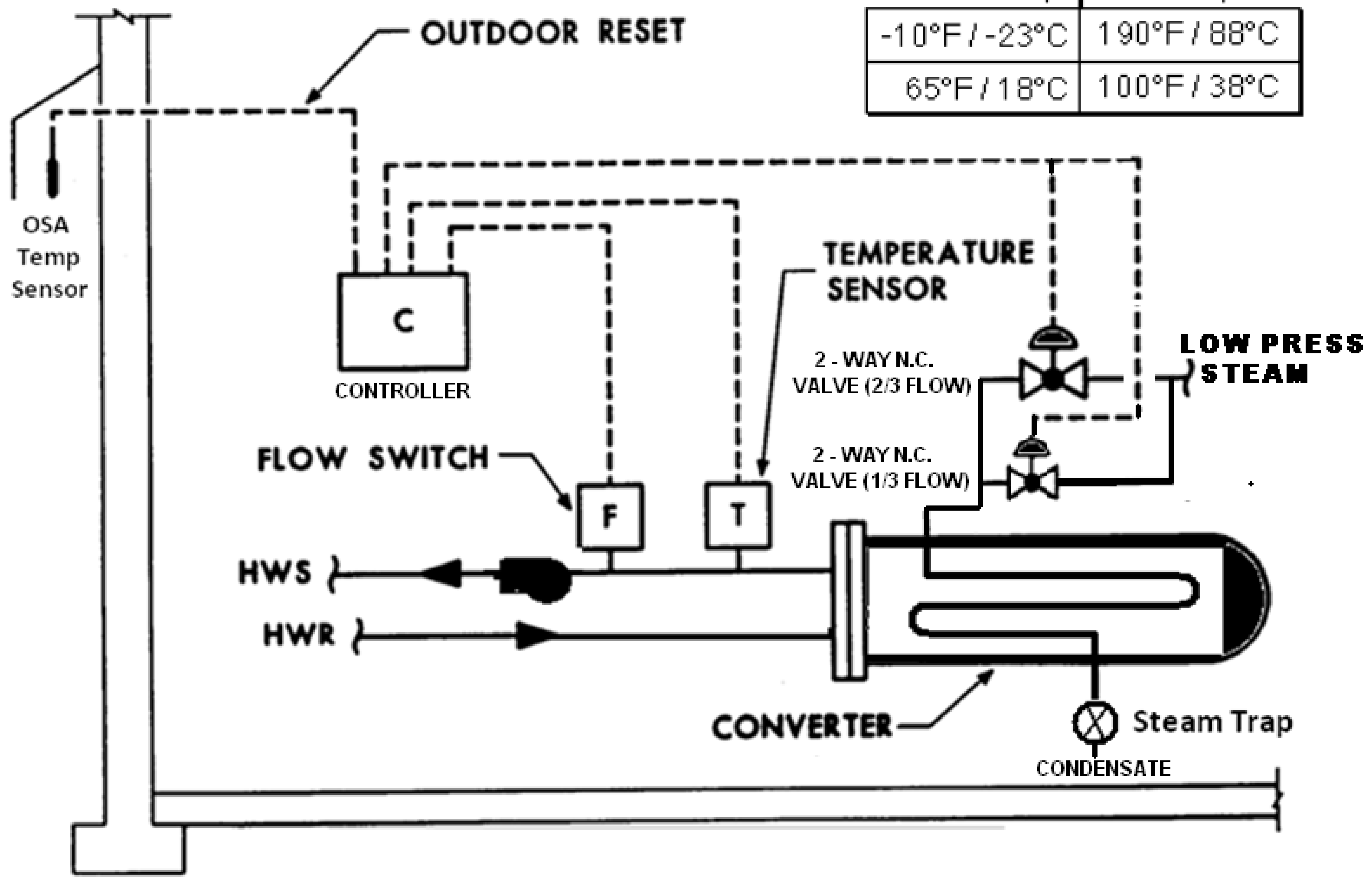



| O. A. Temp | HWS Setpoint |
|---|---|
| 0°F / -18°C | 180°F / 82°C |
| 70°F / 21°C | 90°F / 32°C |

Courtesy TAC Controls/Schneider Electric

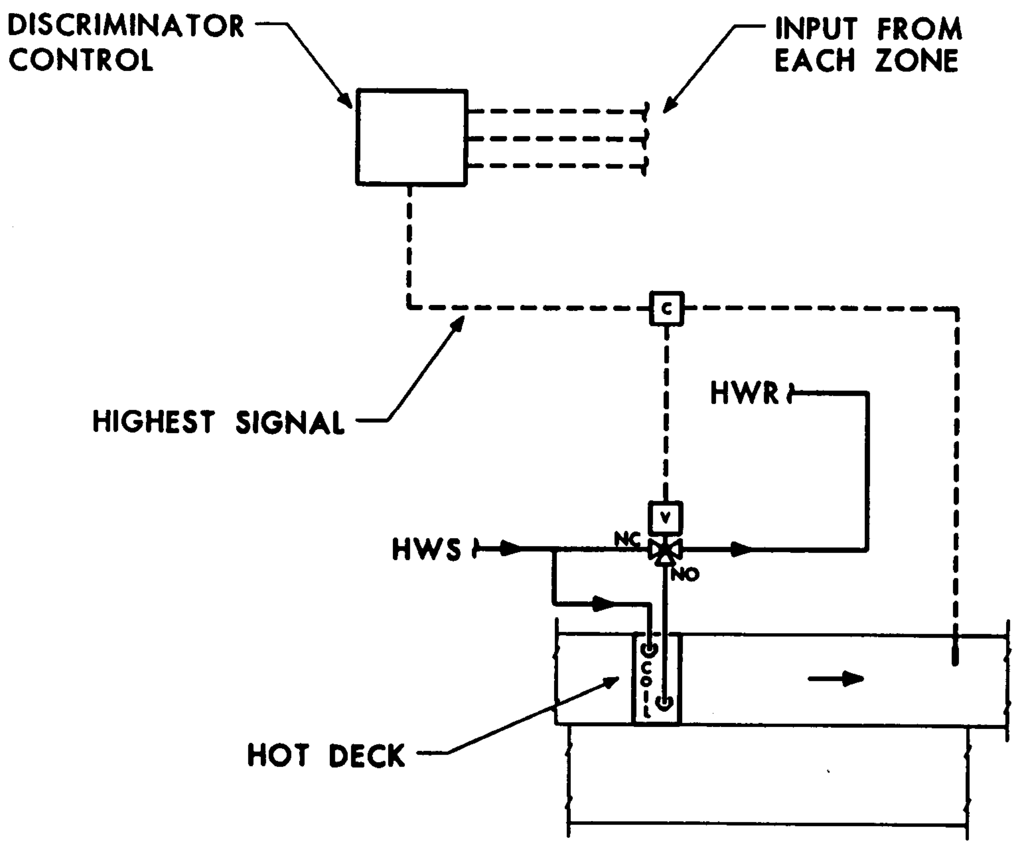
# Converter Control With Reset

| O.A. Temp | HWS Setpoint |
|---|---|
| -10°F / -23°C | 190°F / 88°C |
| 65°F / 18°C | 100°F / 38°C |




Courtesy Northwest Energy Efficiency Council

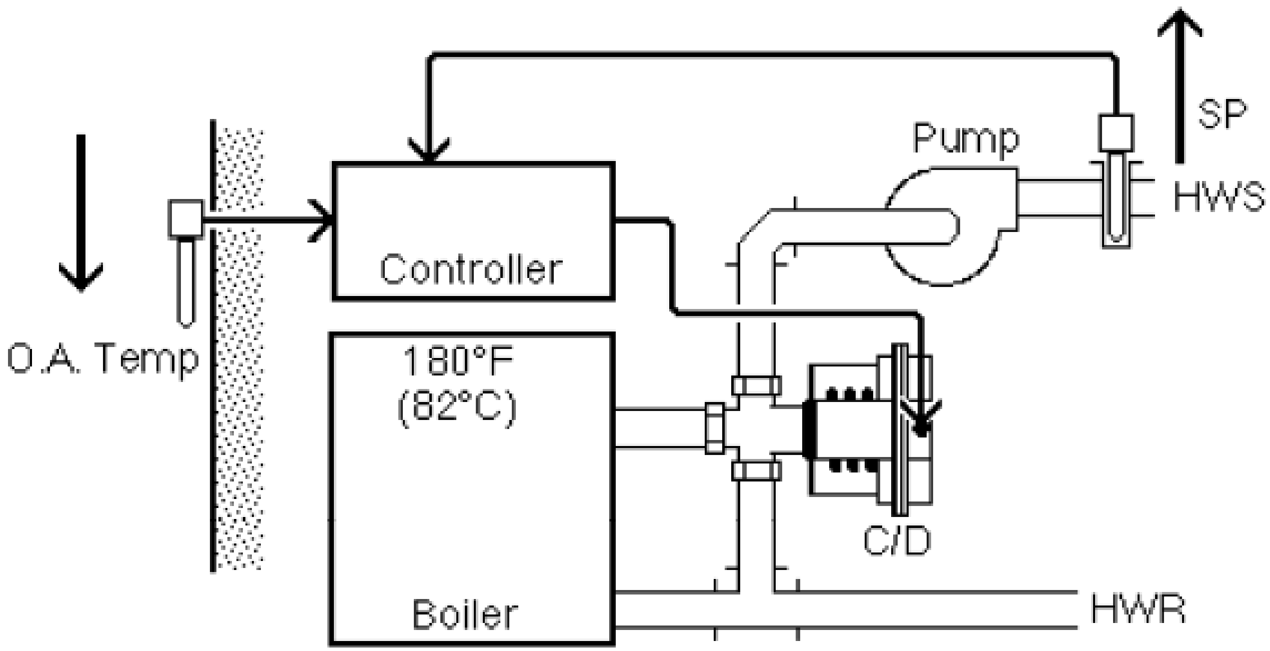
# Air Handler Discharge Air Heating Coil Control With Reset




Courtesy Northwest Energy Efficiency Council

# Reverse Reset

Just as the term “action” is defined as reverse and direct, “reset” is also defined as reverse and direct. The hot water reset, in this example is for *reverse reset.*



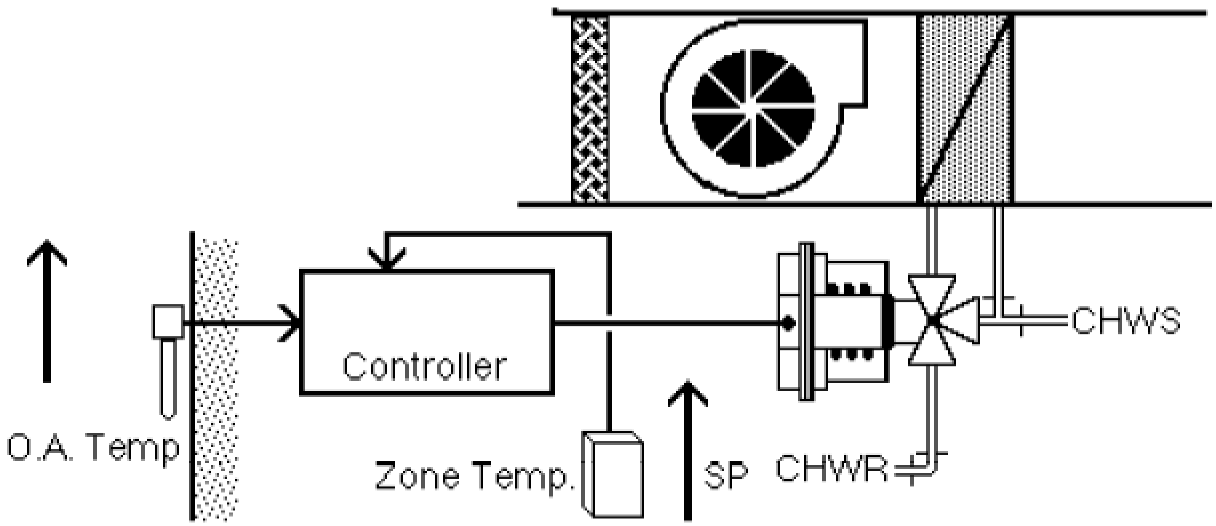

| O. A. Temp | HWS Setpoint |
|---|---|
| 0°F / -18°C | 180°F / 82°C |
| 70°F / 21°C | 90°F / 32°C |

**Reverse Reset Schedule**

Courtesy TAC Controls/Schneider Electric

# Direct Reset

With direct reset, as the signal for the secondary input increases, the setpoint increases. Direct reset is less common than reverse reset. An example of direct reset is an application called “summer compensation”, shown below.



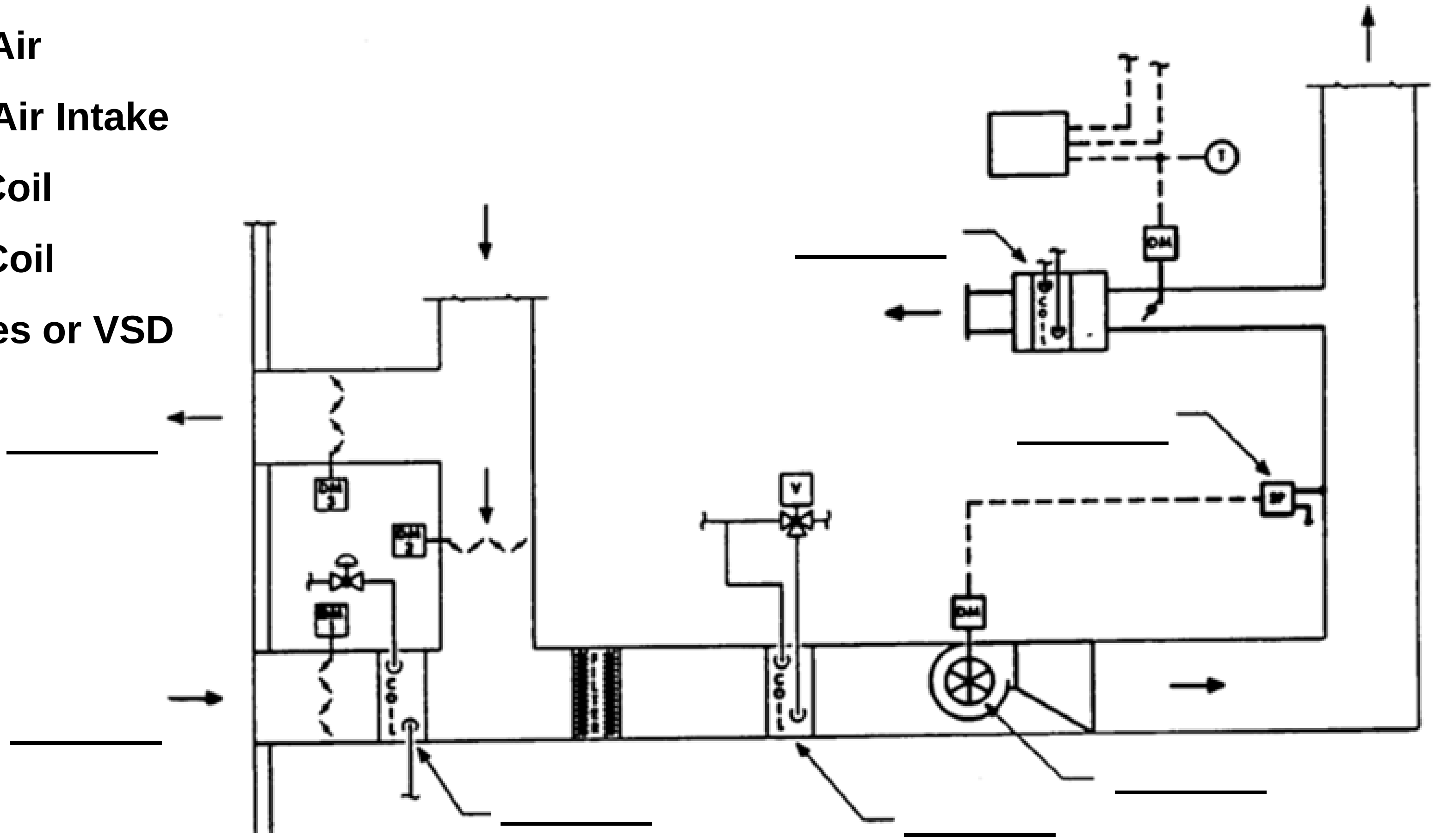

| O. A. Temp | Zone Setpoint |
|---|---|
| 72°F / 22°C | 72°F / 22°C |
| 105°F / 40°C | 78°F / 26°C |

**Summer Compensation Reset Schedule**

Courtesy TAC Controls/Schneider Electric

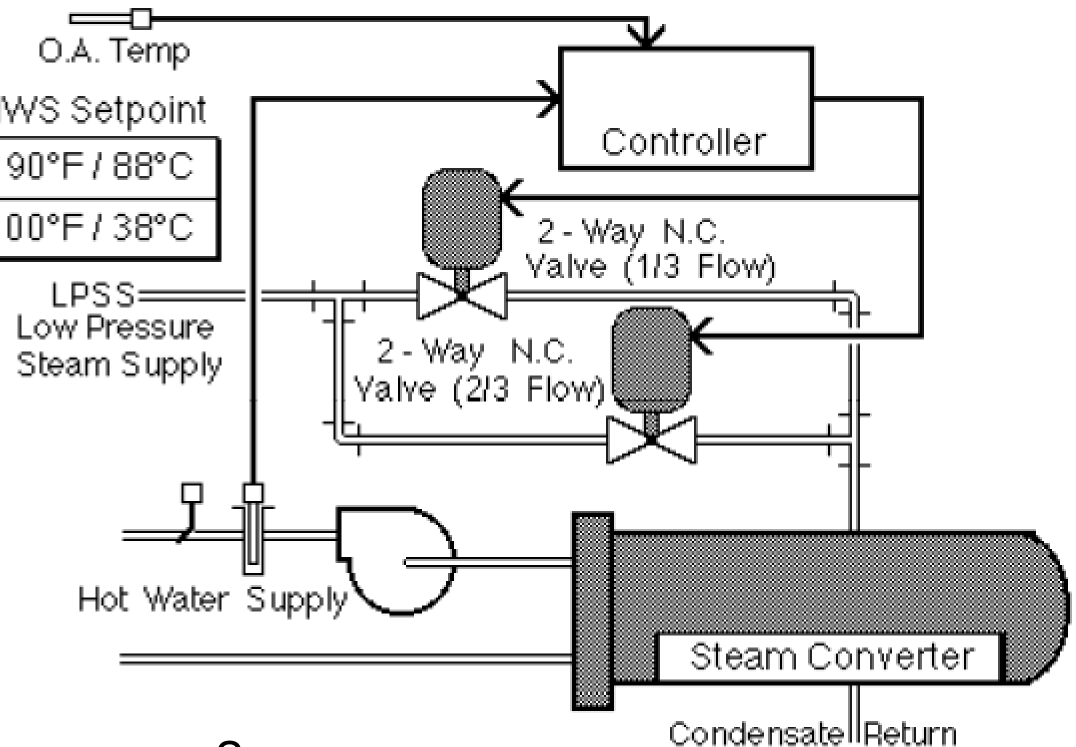
# Exercise
# Identify the component location

1. **Zone Reheat Coil**
2. **Static Pressure Controller**
3. **Exhaust Air**
4. **Outdoor Air Intake**
5. **Preheat Coil**
6. **Cooling Coil**
7. **Inlet Vanes or VSD**



# Exercise
# Converter Control With Reset Schedule

| O.A. Temp | HWS Setpoint |
|---|---|
| -10°F / -23°C | 190°F / 88°C |
| 65°F / 18°C | 100°F / 38°C |

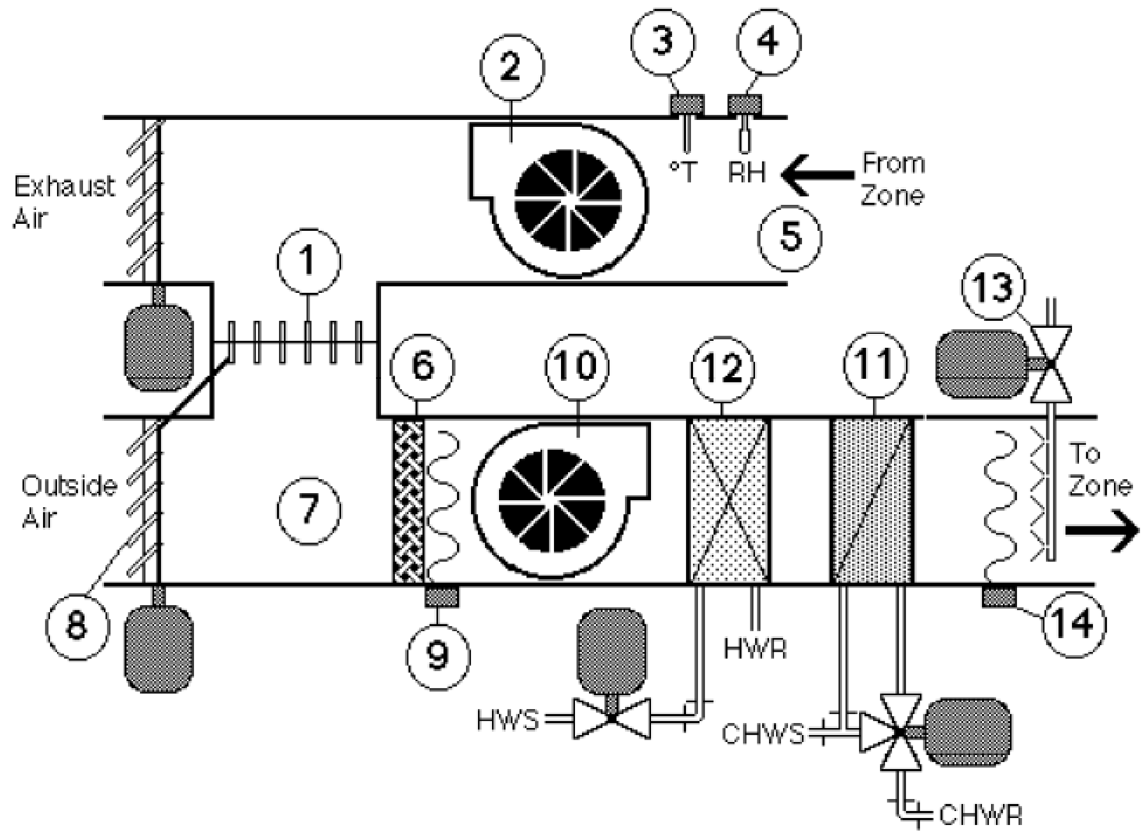



1. Which is the primary sensor?
   Hot Water Supply (HWS) or Outside Air Temperature (OAT)
2. What type of reset is this?
   Direct Reset or Reverse Reset
3. What action is needed at the controller?
   Direct Action or Reverse Action

Courtesy TAC Controls/Schneider Electric

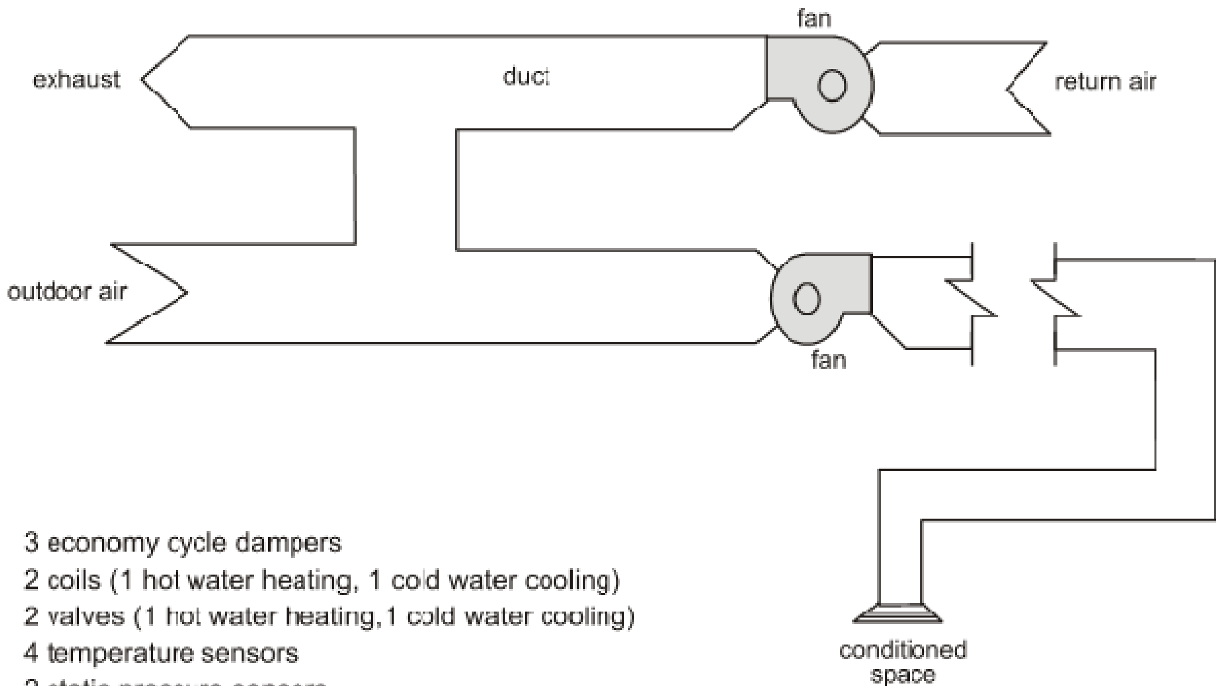
# Exercise-Identify the AHU Components

| | |
|---|---|
| 1.__________ | A. Supply Fan |
| 2.__________ | B. Filter |
| 3.__________ | C. Outside Air Dampers |
| 4.__________ | D. Return Air Temperature Sensor |
| 5.__________ | E. Hot Water Coil |
| 6.__________ | F. Mixed Air |
| 7.__________ | G. Return Air Dampers |
| 8.__________ | H. Return Air Humidity Sensor |
| 9.__________ | I. Discharge Air Temp. Sensor |
| 10.__________ | J. Return Fan |
| 11.__________ | K. Return Air |
| 12.__________ | L. Mixed Air Temperature Sensor |
| 13.__________ | M. Steam Humidifier |
| 14.__________ | N. Chilled Water Coil |

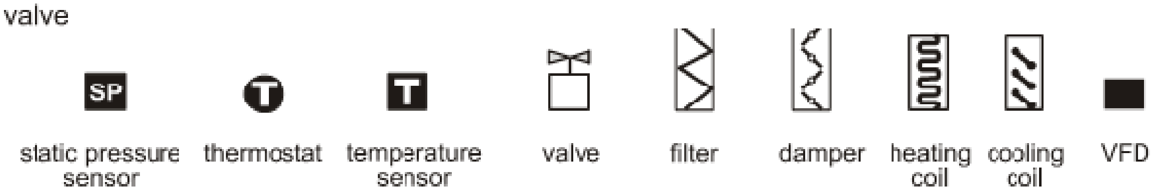



Courtesy TAC Controls/Schneider Electric

# **Exercise** In the illustration of this air handling system, draw in the components that are missing from the diagram using the items in the list.

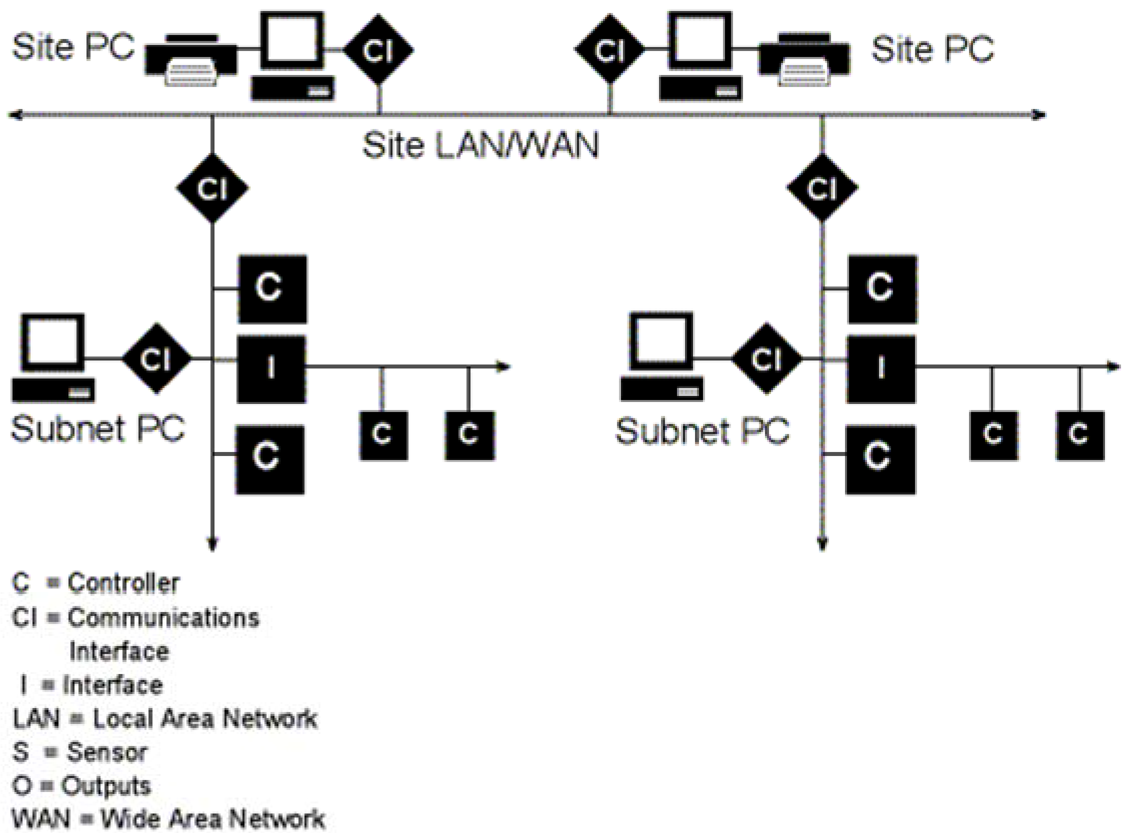



3 economy cycle dampers
2 coils (1 hot water heating, 1 cold water cooling)
2 valves (1 hot water heating, 1 cold water cooling)
4 temperature sensors
2 static pressure sensors
2 variable frequency drives (VFD)
reheat coil and valve
thermostat
air filter




Courtesy Northwest Energy Efficiency Council

# Section 2
# DDC Networks and Architecture
## Large Systems

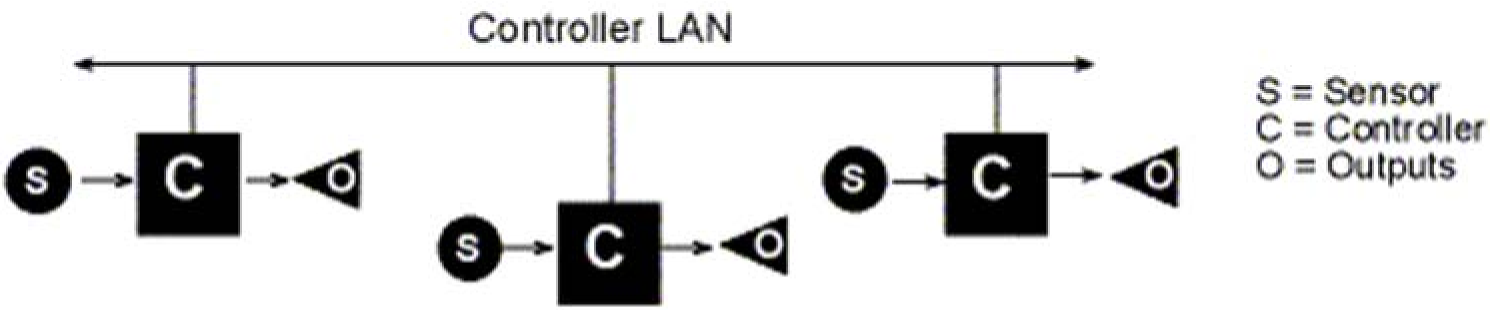



Multiple-Subnet Works System Architecture

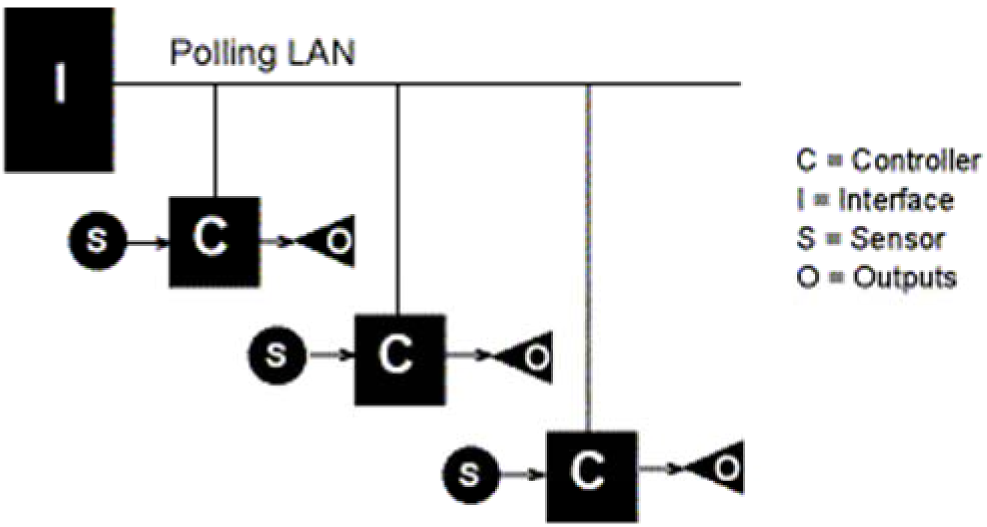
Courtesy DDC-Online Org

# DDC Networks and Architecture

## LAN Configurations




Peer-to-Peer LAN Diagram

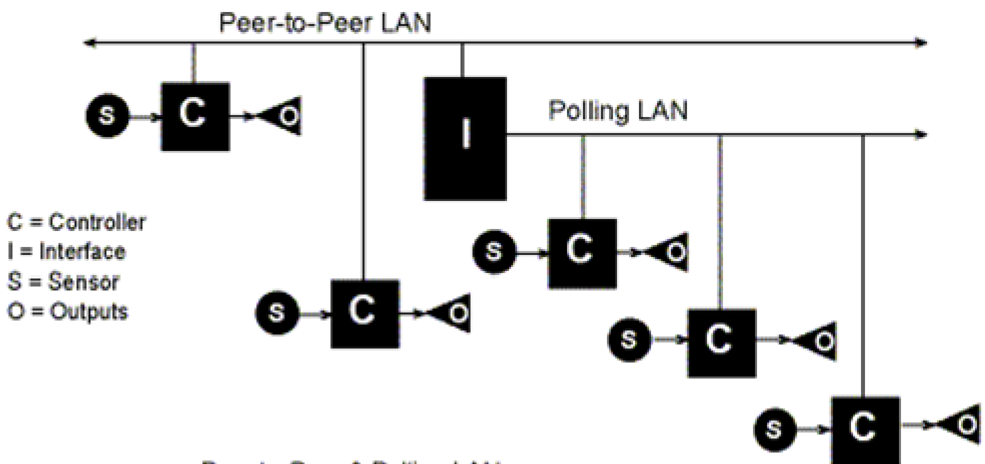



Polling LAN Diagram

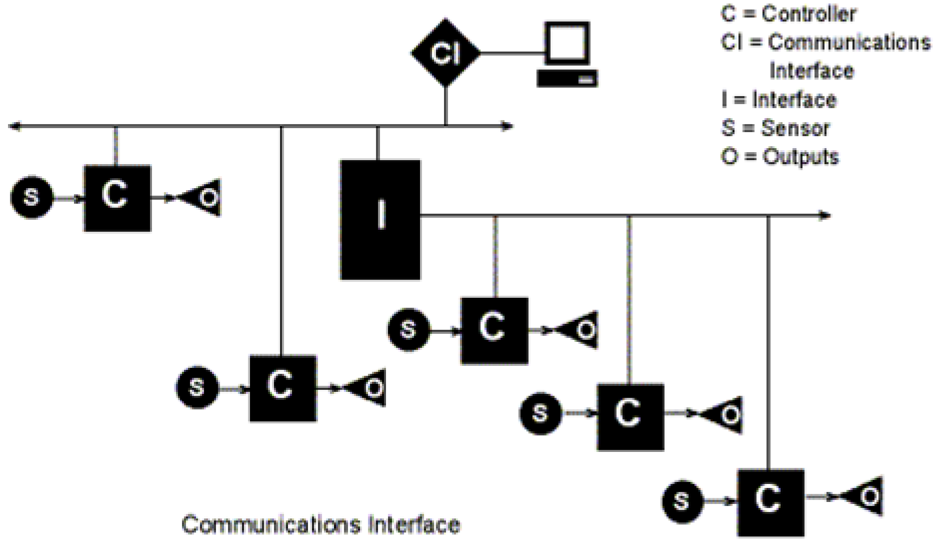
Courtesy DDC-Online Org

# DDC Networks and Architecture

## LAN Configurations



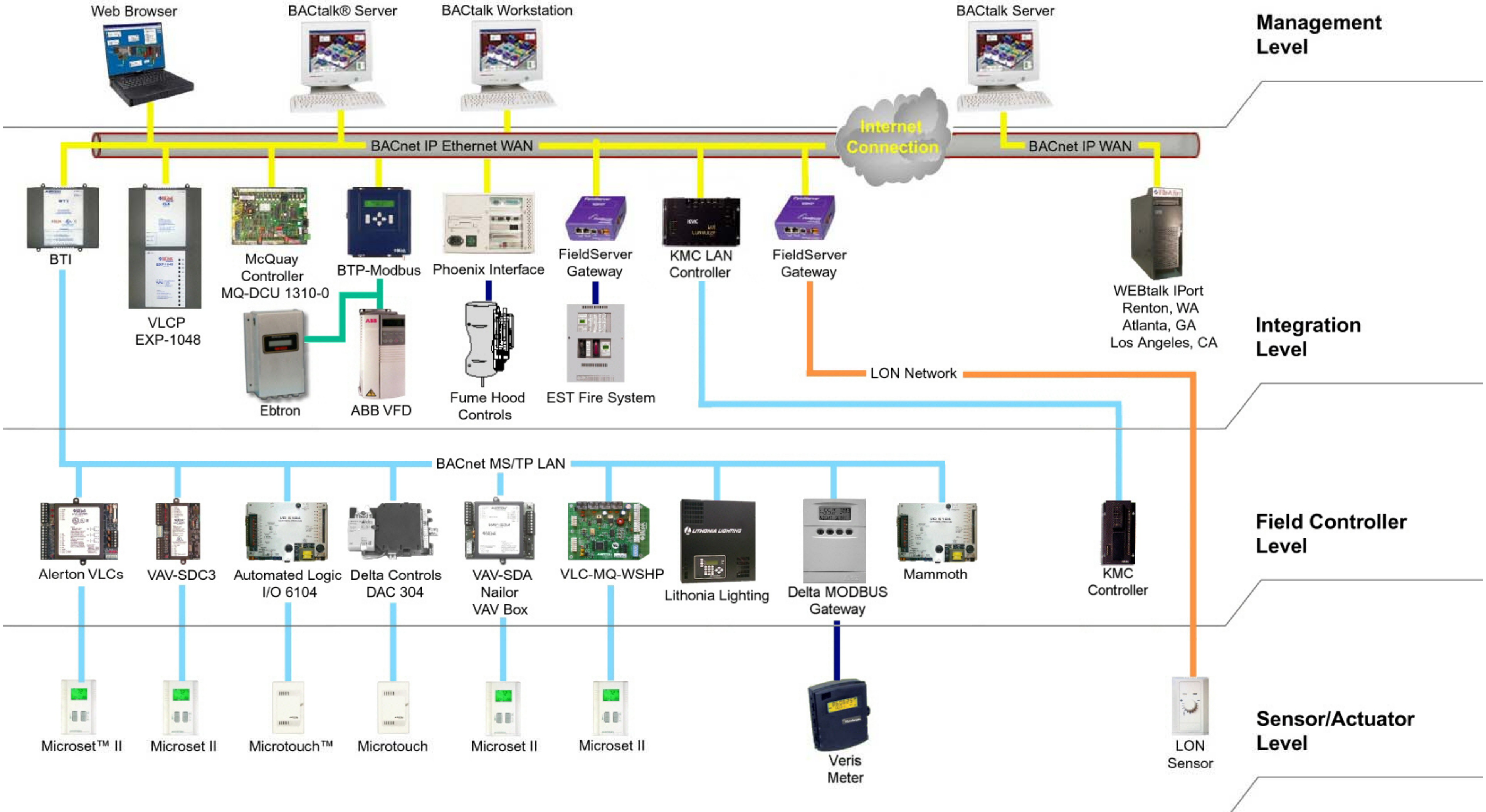

Peer-to-Peer & Polling LAN




Communications Interface

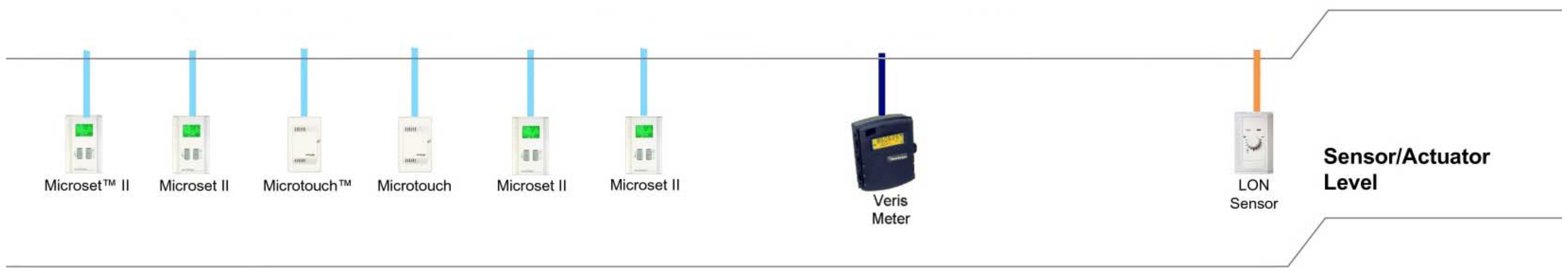
Courtesy DDC-Online Org

# Modern DDC Controls Have
## Four Level Architecture



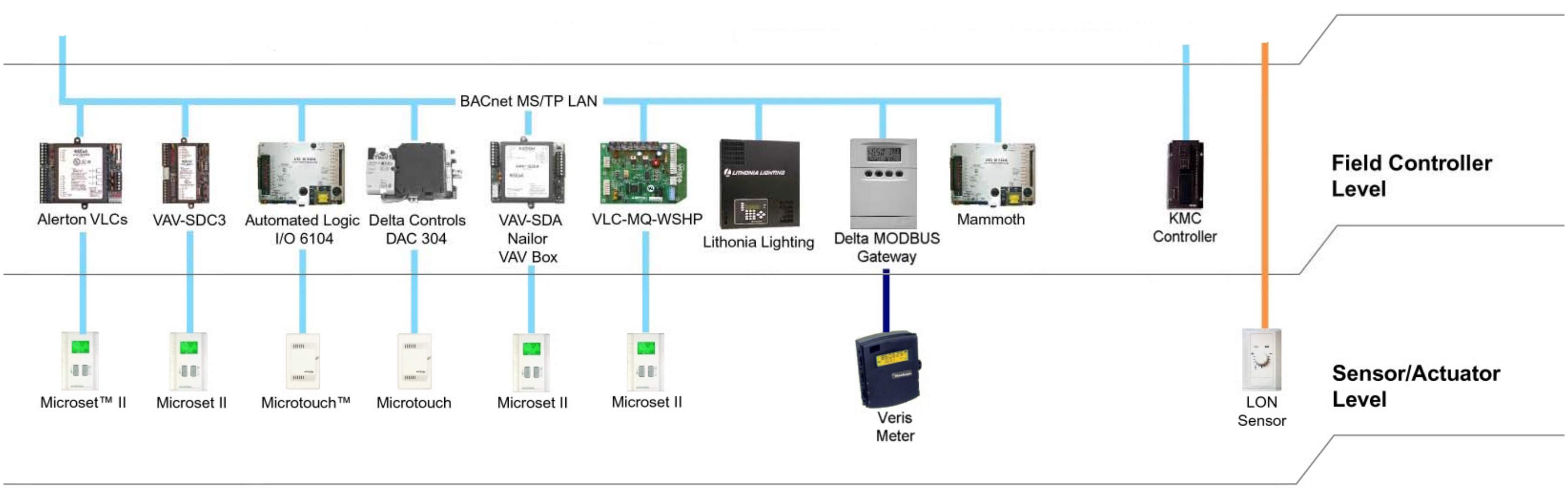

Courtesy Alerton Controls

# Four Level Architecture
# Level One "Sensors"



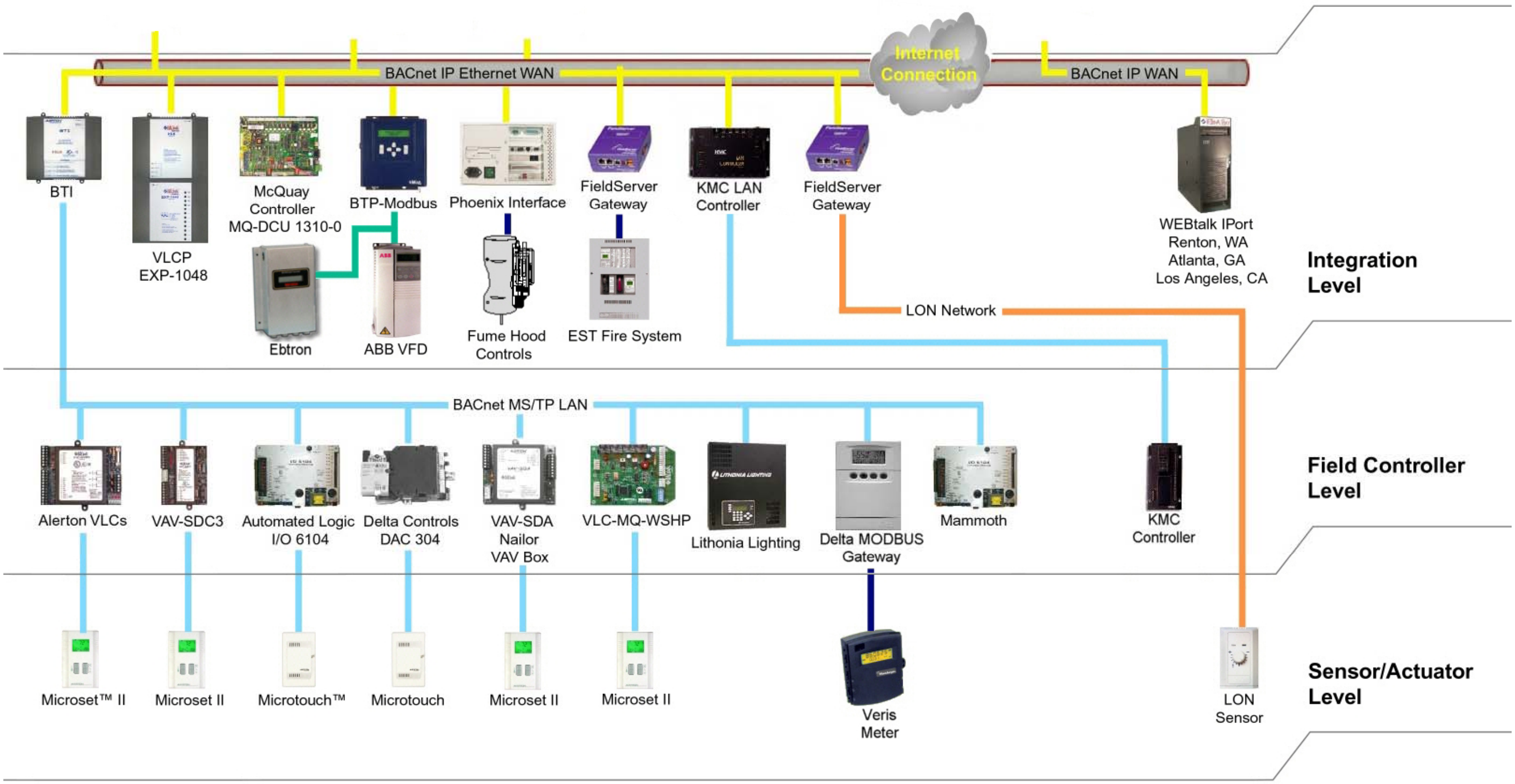

Courtesy Alerton Controls

# Four Level Architecture
# Level Two "Field Controllers"



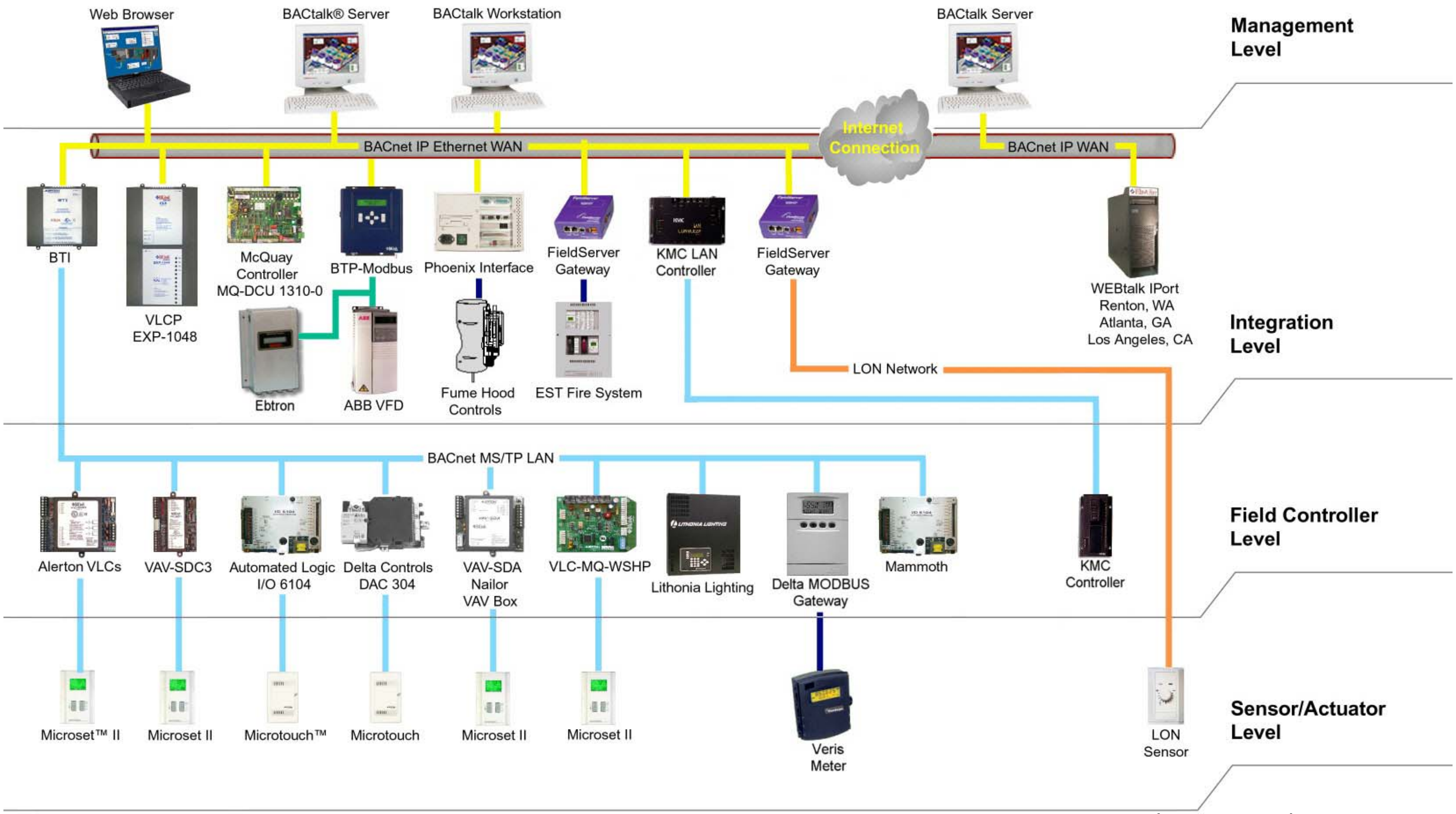

Courtesy Alerton Controls

# Four Level Architecture
# Level 3 "Integration"




Courtesy Alerton Controls

# Four Level Architecture
# Level 4 “Management”




Courtesy Alerton Controls

# Section 3
# Communication Standards
# Software Integration
# (TCP/IP, BACnet, LON)

Automation systems allow communication with multiple vendors including:

- HVAC equipment
- Fire alarm, security
- Lighting, fan units
- PLCs (programmable logic controllers)
- Boilers and chillers

# Interoperability and Open Systems

## Proprietary Systems vs. Open Systems

### Terms

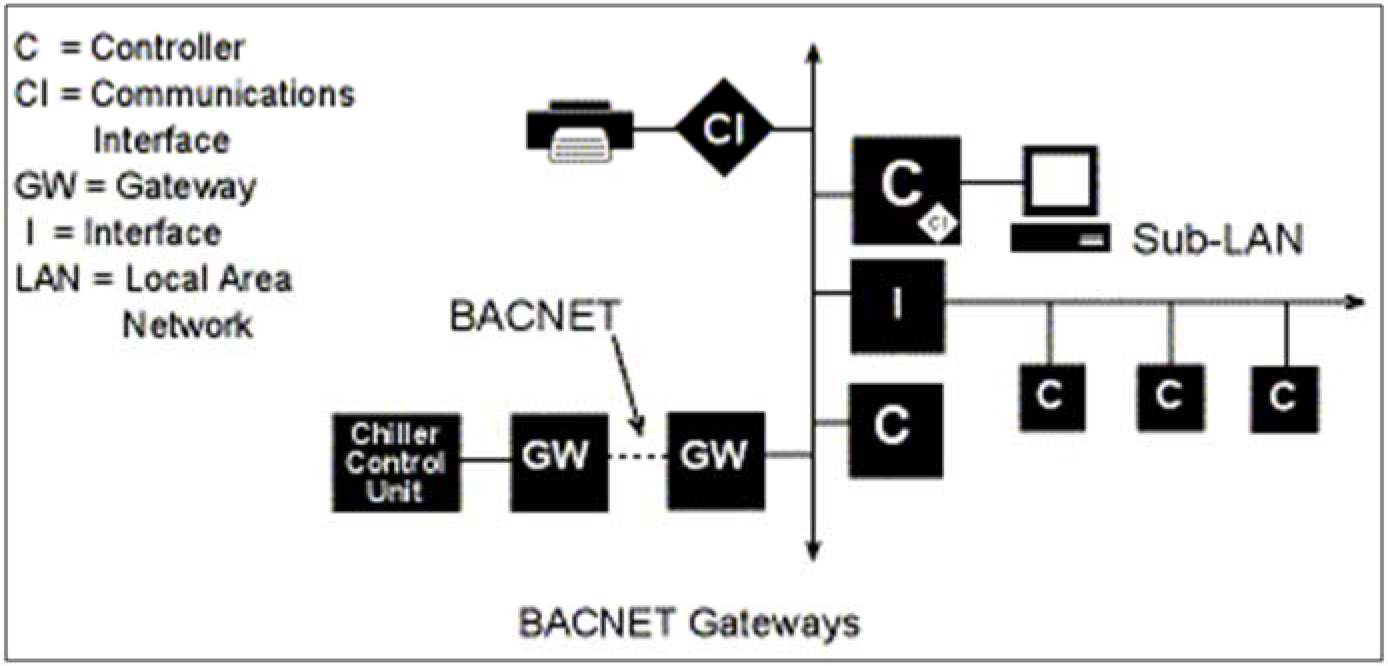
- Interoperability
- Connectivity
- Interchangeability

# BACnet Software Standard Protocol

- BACnet, was developed by ASHRAE
- True, Non-proprietary, Open Protocol
- Industry Standardized
- Multiple Vendor Controllers

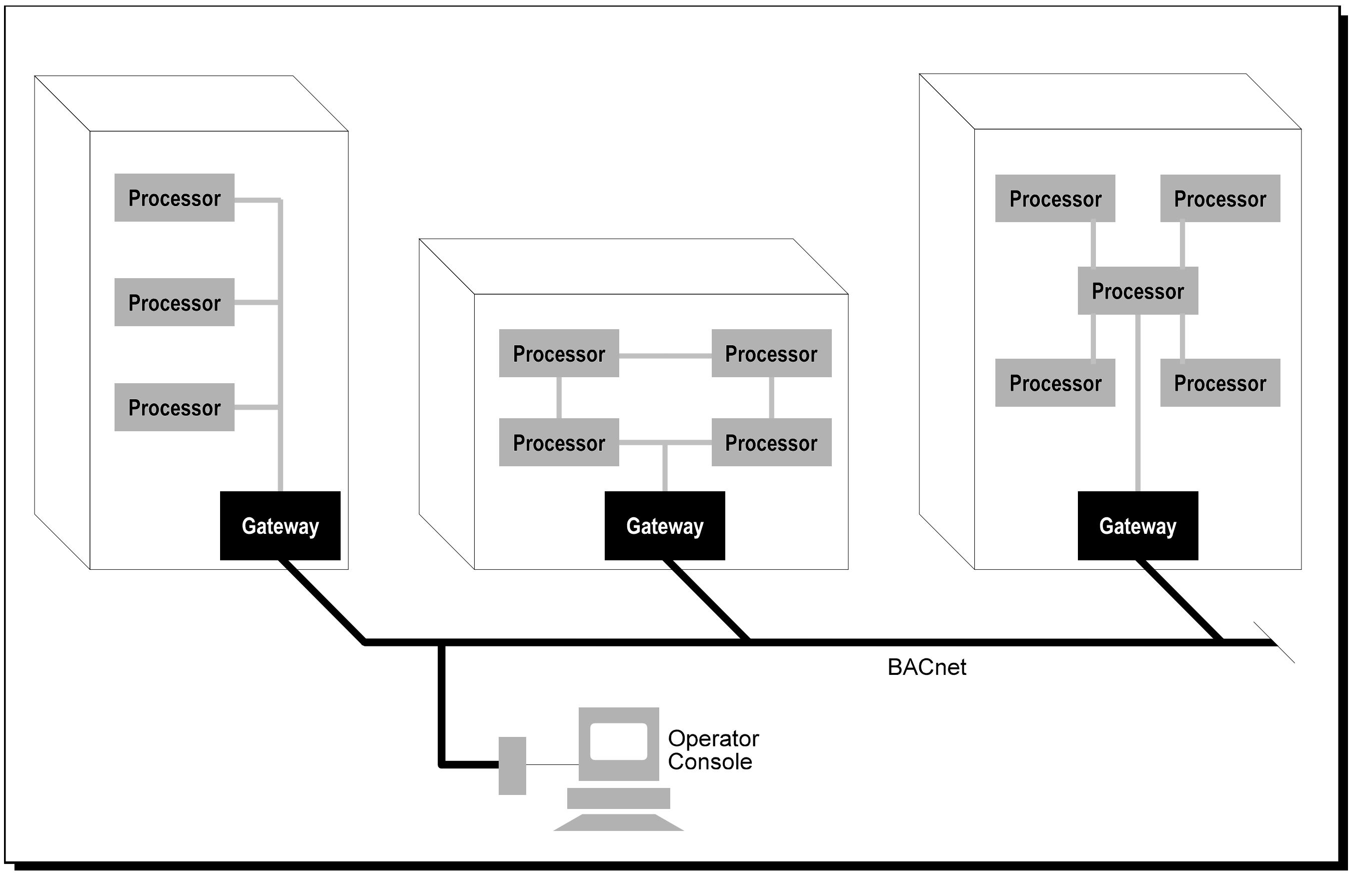

Courtesy York/Johnson Controls

# BACNet Gateways

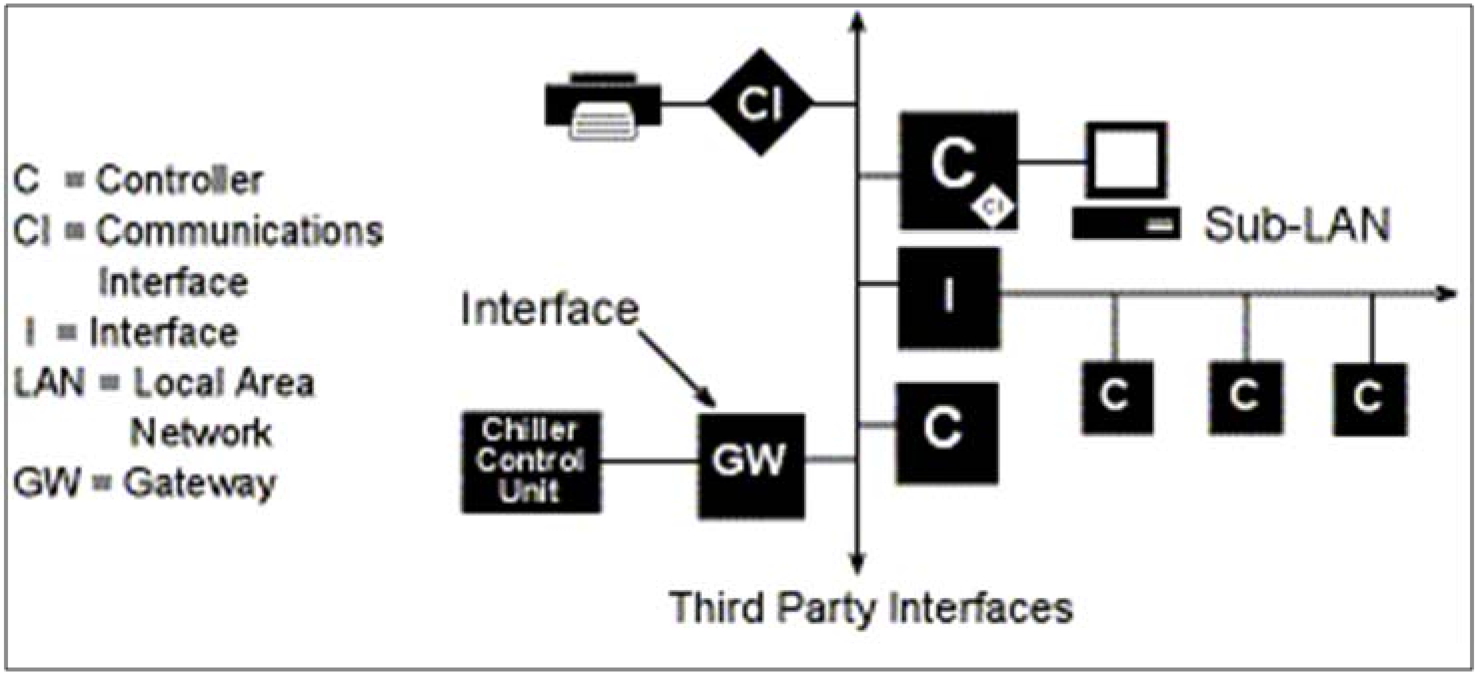



Courtesy DDC-Online Org

# BACnet Connectivity

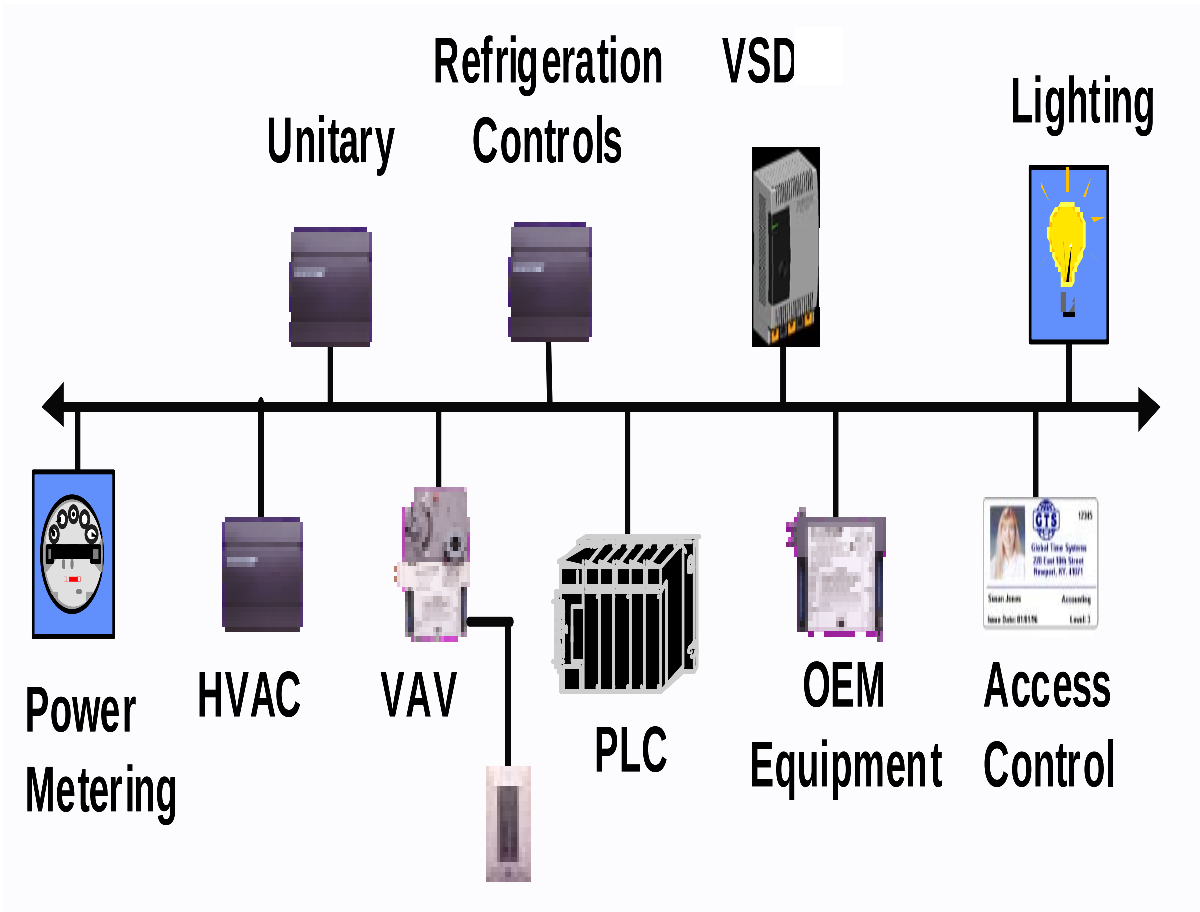


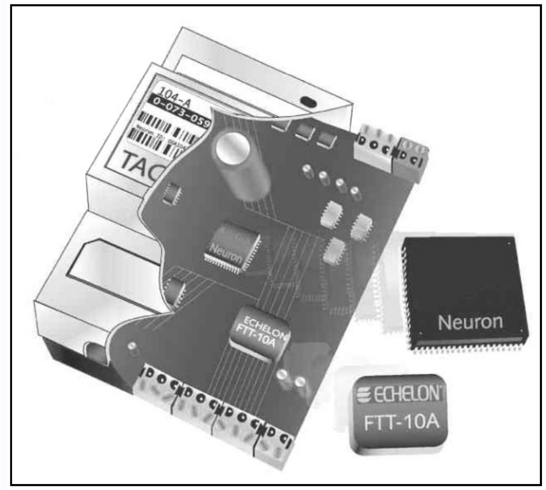
# Third Party Interface




Courtesy DDC-Online Org

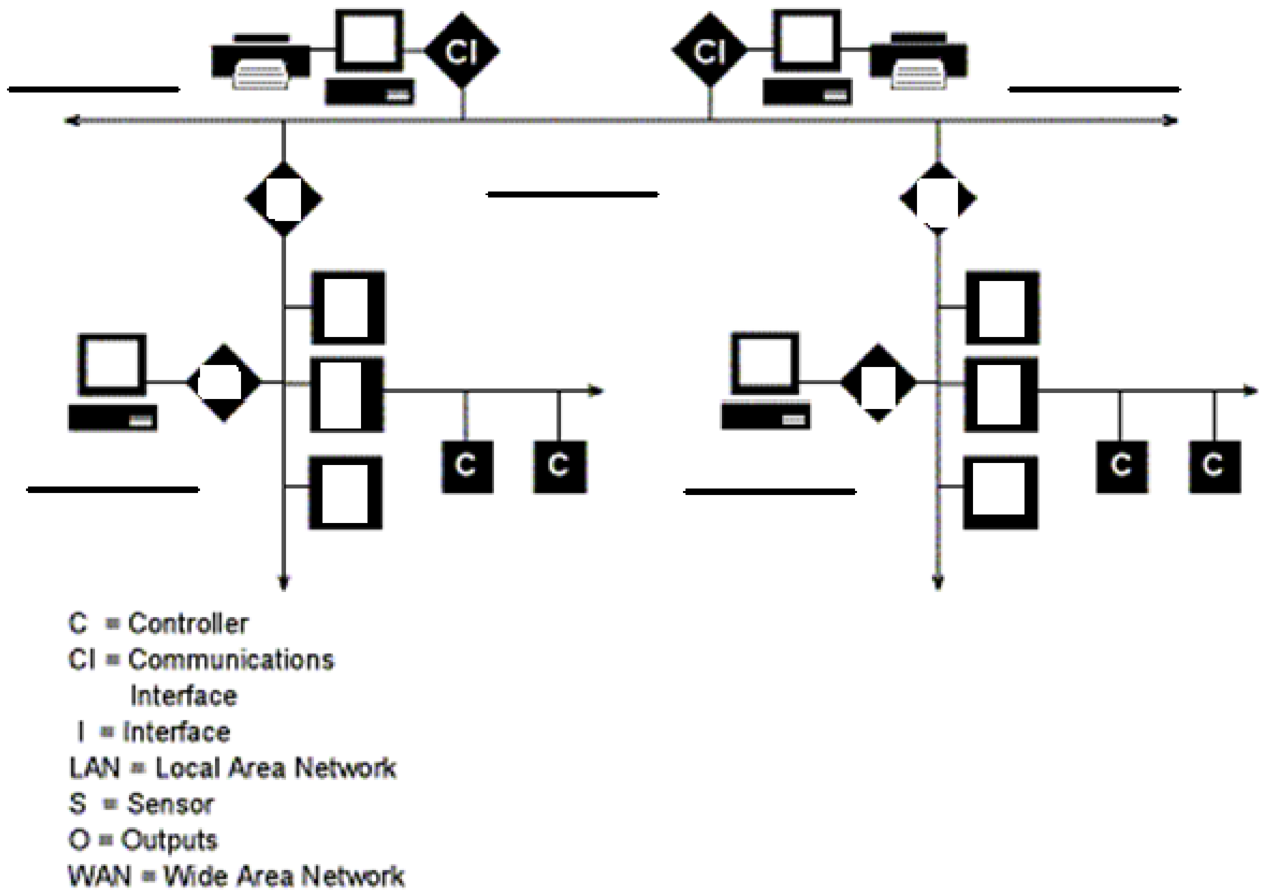
# LonWorks Platform and LONTalk (Open Protocol) by a Proprietary Manufacturer-Echelon




**TAC Factory Lon Board and Lon Talk Neuron Chip by Echelon**

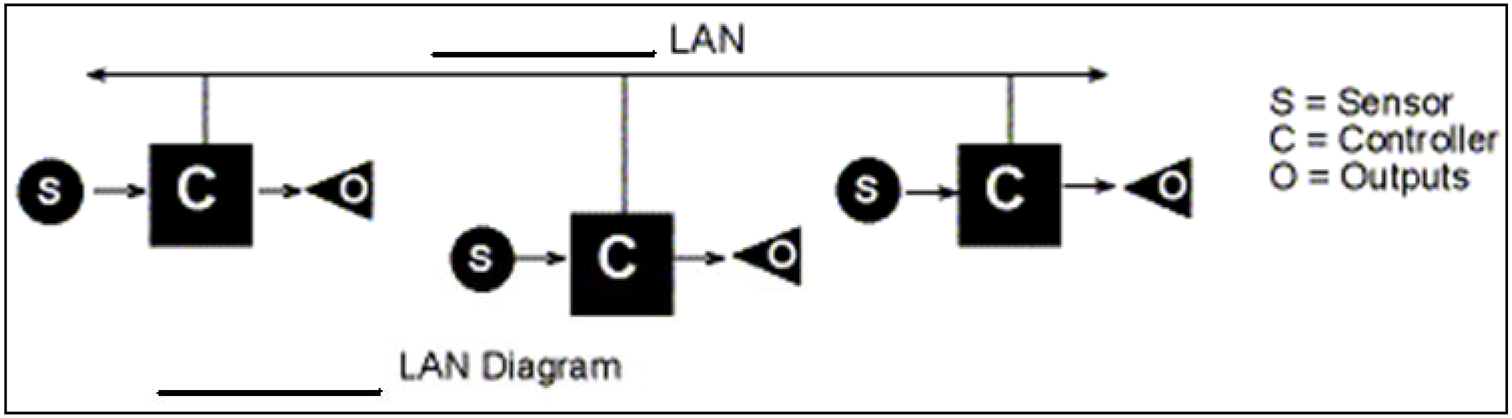
# Exercise
## Identify the Components of the Large System DDC Network, Fill in the Blanks

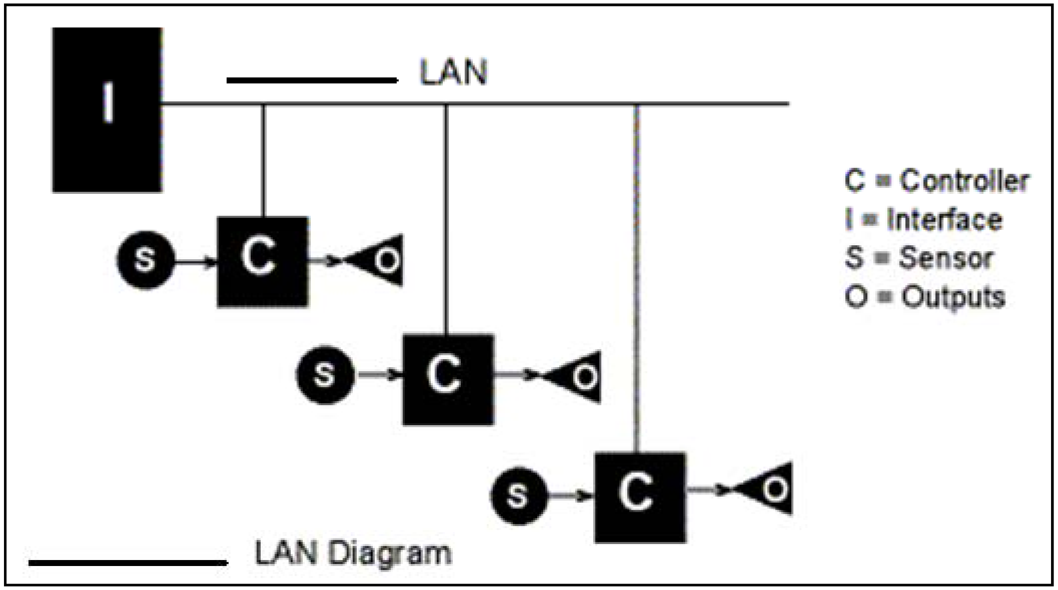



Multiple-Subnet Works System Architecture

# Exercise

## Identify which DDC LAN Network is Polling and which is a Controller LAN Network

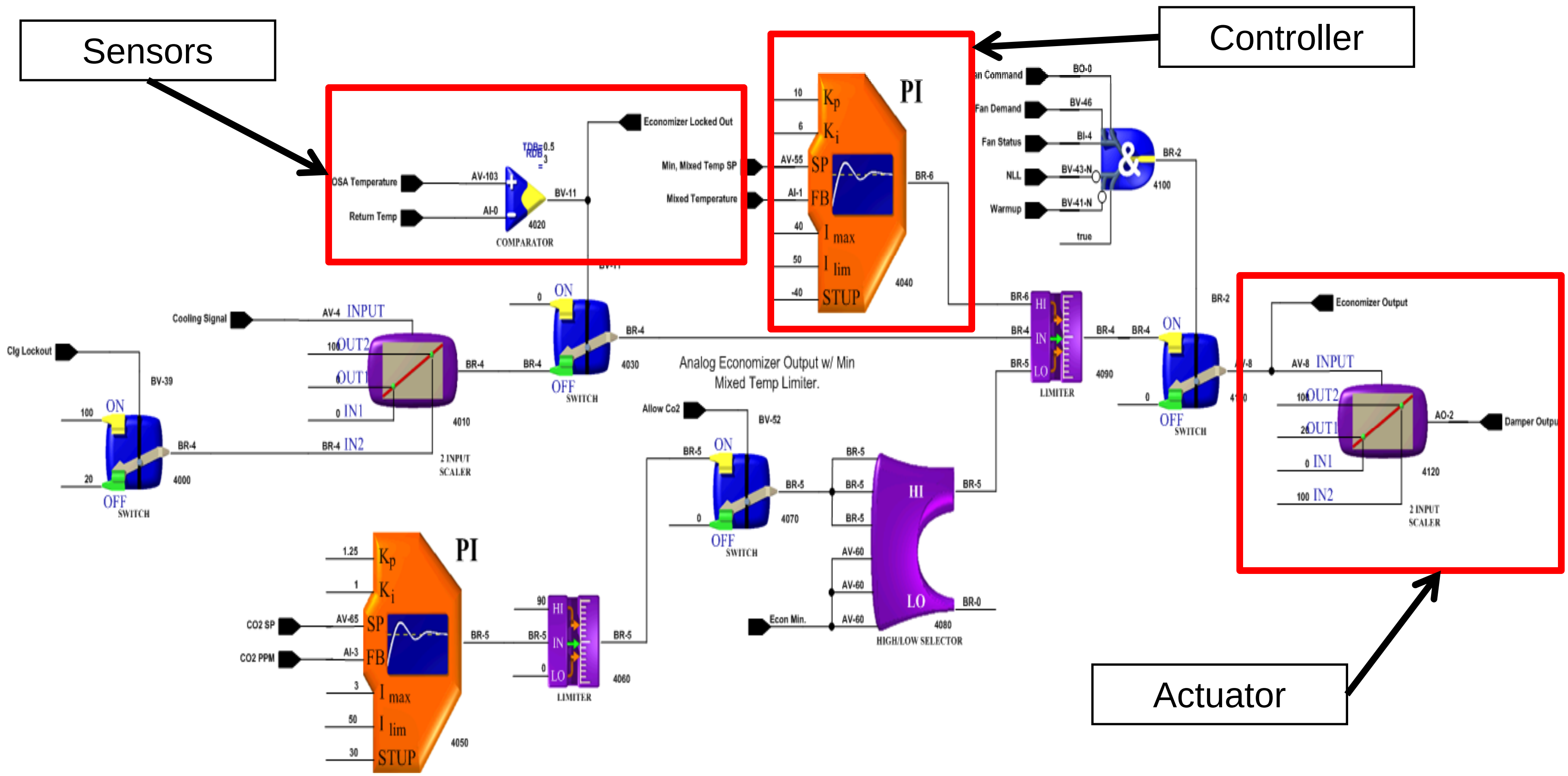


# Section 4
# Vendor Examples of Software
## Programming and Graphical Interface Strategies

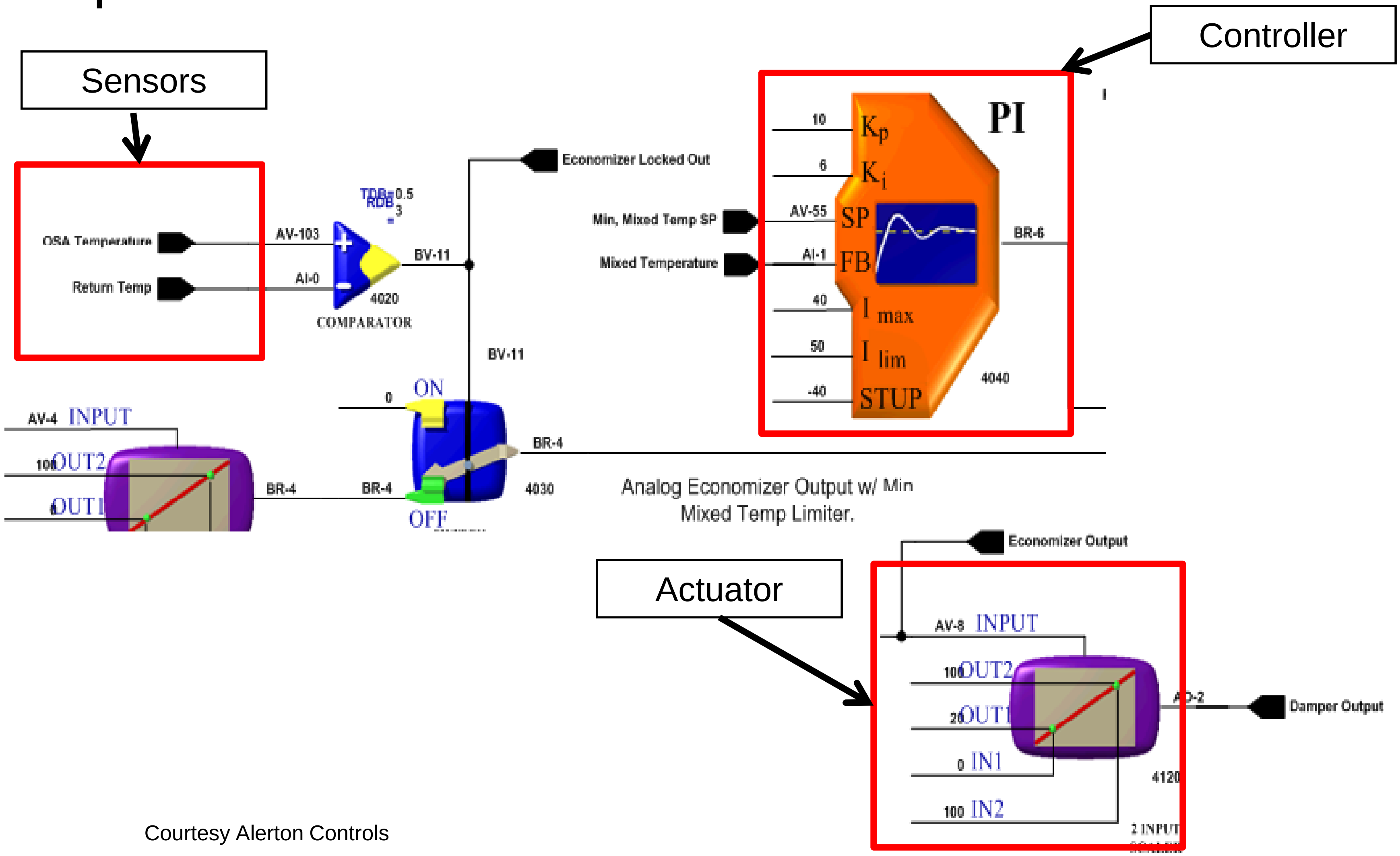
- Alerton Controls
- Siemens Building Technologies
- AutomatedLogic

# Typical Controls on Factory AHU Example of Economizer Program for Alerton Controls




Courtesy Alerton Controls

# Typical Controls on Factory AHU Example of Economizer Program Components for Alerton DDC



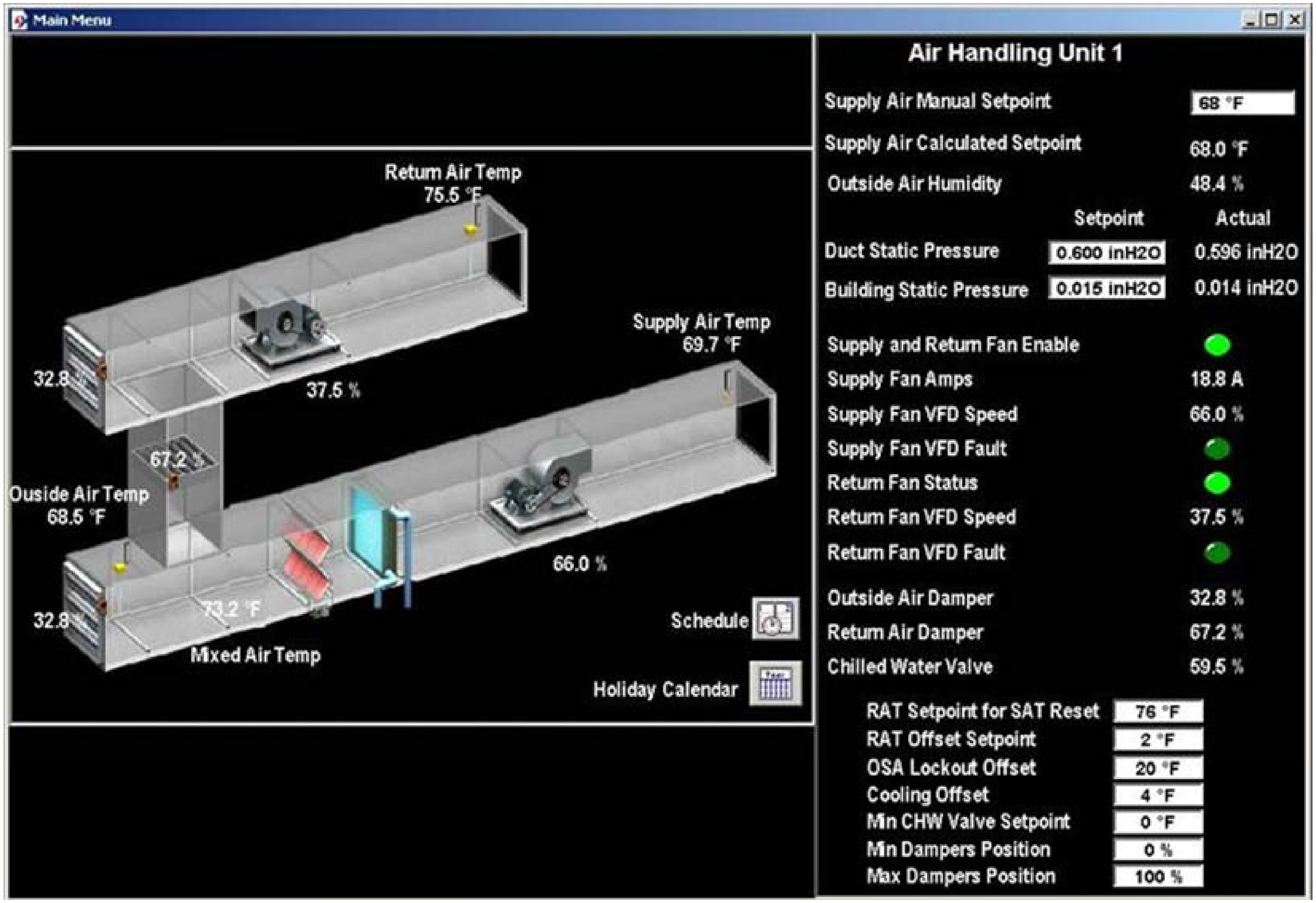

Courtesy Alerton Controls

# Typical Controls on Factory AHU

## Example of Program

```
Process 'Energy\100KW' "Rm100 Energy" '\NCM-22'
PERIOD 00:01:00
Exempt All
Shared SF1DAT!,RmTemp100!,Rm100VentKW!,RM100ClgKW!,Rm100HtgKW!,ClgCmd!(1),HtgCmd!(1)
PRIORITY 4
Rem inputs

CFM! =    'Rm-100\CS-Obj\AD_3'
CFMSetPt!='Rm-100\CS-Obj\AO_3'
HtgCmd! = 'Rm-100\CS-Obj\AO_1'
MinCFM! = 'Rm-100\CS-Obj\SP_8'  :Rem MinCFM Cooling
MaxCFM! = 'Rm-100\CS-Obj\SP_7'  :Rem MaxCFM Cooling

CoilKW! = 4.3

ClgCmd! = Span(CFMSetPt!,MinCFM!,MaxCFM!,0,100)

If (HtgCmd! < 1) and (ClgCmd! > 1) then
    ClgKW! = 1.08 * abs(RmTemp100! - SF1DAT!) * (CFM! - MinCFM!) / 3412
    VentKW! = 1.08 * abs(RmTemp100! - SF1DAT!) * MinCFM! / 3412
    HtgKw! = 0.0
    HtgCmd(1) = 0.0
    ClgCmd!(1) = ClgCmd!
    ModeA! = 2

            ………
```

# Typical Controls AHUs-Example of AutomatedLogic Graphics Display for Central AHU Controls



# Section 5
# Understanding the Sequence of Operations for DDC Controls

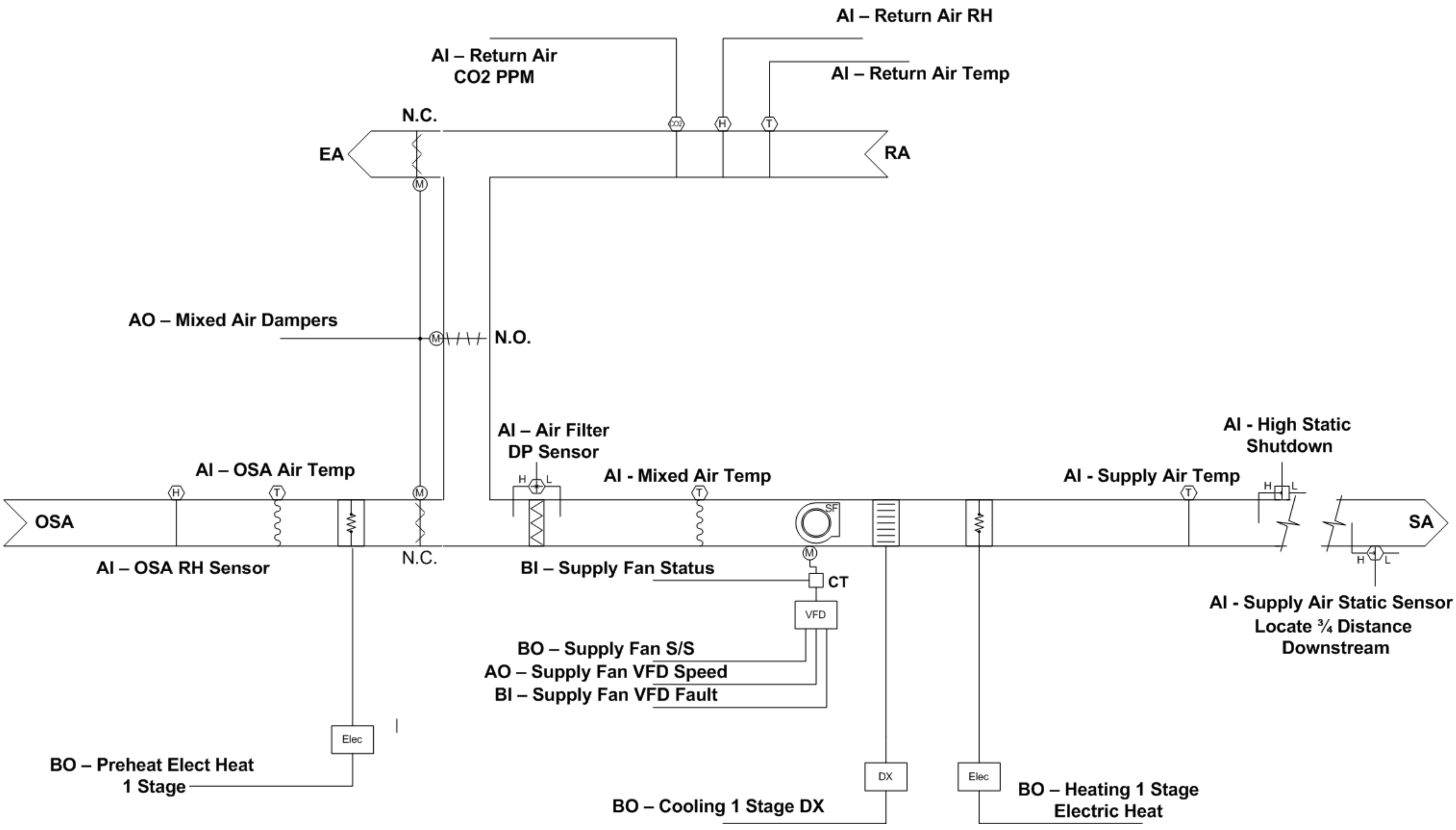
The sequence of operation explains:

**“How the System is Designed to Operate” while linking the Operation with the Control Drawing”**

It will include:

- Unit startup and shutdown
- Supply fan static pressure control
- Cooling cycle and economizer operation
- Heating cycle
- Safety and limits

# The Control Drawing is the Field Picture for the Sequence of Operation



# Examples-Sequence of Operations for Unit and Fan Run and Shutdown

Unit Run Conditions:

- The initial duct static pressure setpoint shall be 0.5 in. $H_2O$

Supply Fan:

- The supply fan shall run anytime the unit is programmed or commanded to run, unless shutdown on safety resason. To prevent short cycling, the supply fan shall have a user definable minimum runtime.

AHU Optimal Start:

- The unit shall start prior to scheduled occupancy based on the time necessary for the zones to reach their occupied setpoints. The start time shall automatically adjust based on changes in outside air temperature and zone temperatures.

# Examples-Sequence of Operations for Supply Fan Static Pressure Control

Supply Air Duct Static Pressure Control:

- The controller shall measure duct static pressure and modulate the supply fan VFD speed to maintain a duct static pressure setpoint. The speed shall not drop below 30% (adj.).

Setpoint Control

- The static pressure setpoint shall be reset based on zone cooling requirements. The initial duct static pressure setpoint shall be 0.5 in. $H_2O$ (adj.).
- As cooling demand increases, the setpoint shall incrementally reset up to a maximum of 0.75 in. $H_2O$ (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset down to a minimum of 0.25 in. $H_2O$ (adj.) .

# Examples-Sequence of Operations for the Cooling Cycle

Cooling Stage Control:

•The controller shall measure the supply air temperature and stage the DX cooling to maintain its cooling setpoint. To prevent short cycling, the stage shall have a user definable (adj.) minimum runtime and differential setpoint.

The cooling shall be enabled whenever:

•Outside air temperature is greater than 60°F (adj.), AND the economizer is closed to a minimum, AND the supply fan status is on, AND the heating is not active.

# Examples-Sequence of Operations for the Economizer Operation

Economizer:

- The controller shall measure the mixed air temperature and modulate the economizer dampers in sequence to maintain a setpoint 2°F (adj.) less than the supply air temperature setpoint. The outside air dampers shall maintain a minimum adjustable position of 10% (adj.) open whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.), AND the outside air temperature is less than the return air temperature, AND the supply fan status is on.

The economizer shall close to minimum (or close) whenever:

- Mixed air temperature drops from 40°F to 35°F (adj.), OR on fully close on loss of supply fan status or shutdown.

# Examples-Sequence of Operations for the Heating Cycle

Electric Heating Stage:

- The controller shall measure the supply air temperature and stage the heating to maintain its heating setpoint. To prevent short cycling, the stage shall have a user definable (adj.) minimum runtime.

The heating shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.), AND the supply fan status is on, AND the cooling (if present) is not active.

The heating stage shall run for freeze protection whenever:

- Supply air temperature drops from 40°F to 35°F (adj.), AND the supply fan status is on.

# Exercise

Fill in the blanks or circle T or F, as needed to the following questions:

1.) The supply fan speed shall not drop below _____.

2.) The initial duct static pressure setpoint shall be ____$H_2O$ .

3.) The outside air dampers will go to a minimum setting whenever the outside air temperature is greater than __°F and the fan is ________________.

4.) T F The heating shall be enabled whenever the outside air temperature is less than 55°F.

5.) T F The cooling shall be enabled whenever the outside air temperature is greater than 60°F.

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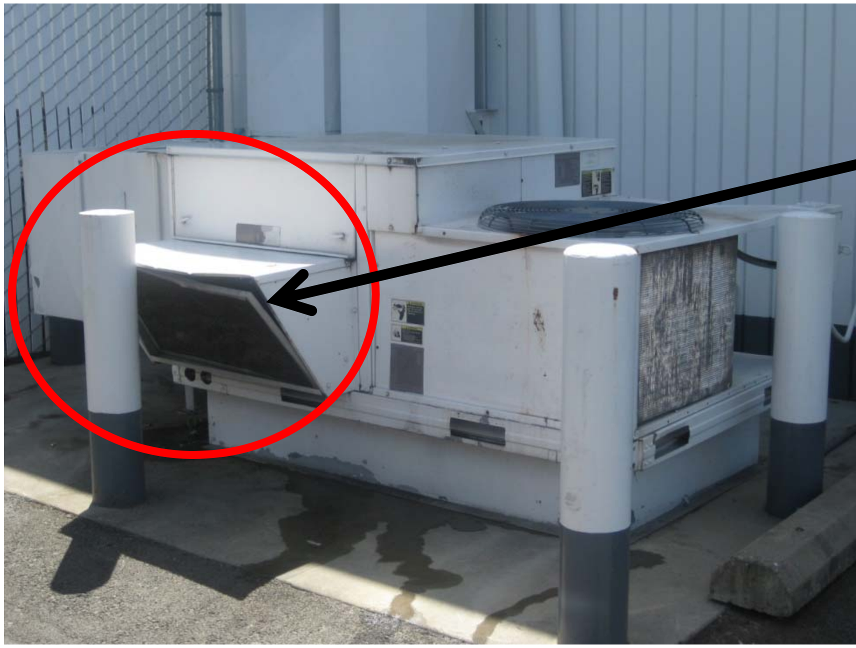
# Section 6

## System Maintenance & Service of HVAC/DDC Controls and Associated Equipment

- Fix Obvious Problems
- Minimizing Nuisance Alarms
- Trending and Recording
- Setpoint vs. Control Point
- Monitoring Graphics
- Calibrating Pneumatics
- Air Compressor Checkout
- Routine Inspection on VAV Boxes and AHU Coils
- Calibrating DDC Panels
- Loop Tuning

# Fix Obvious Problems
# Outside Air Intake-Is this a Problem?



Notice the condition of the outdoor air intake screens

# Fix Obvious Problems
# Is the Damper Operator a Problem?

Notice the disconnected linkage

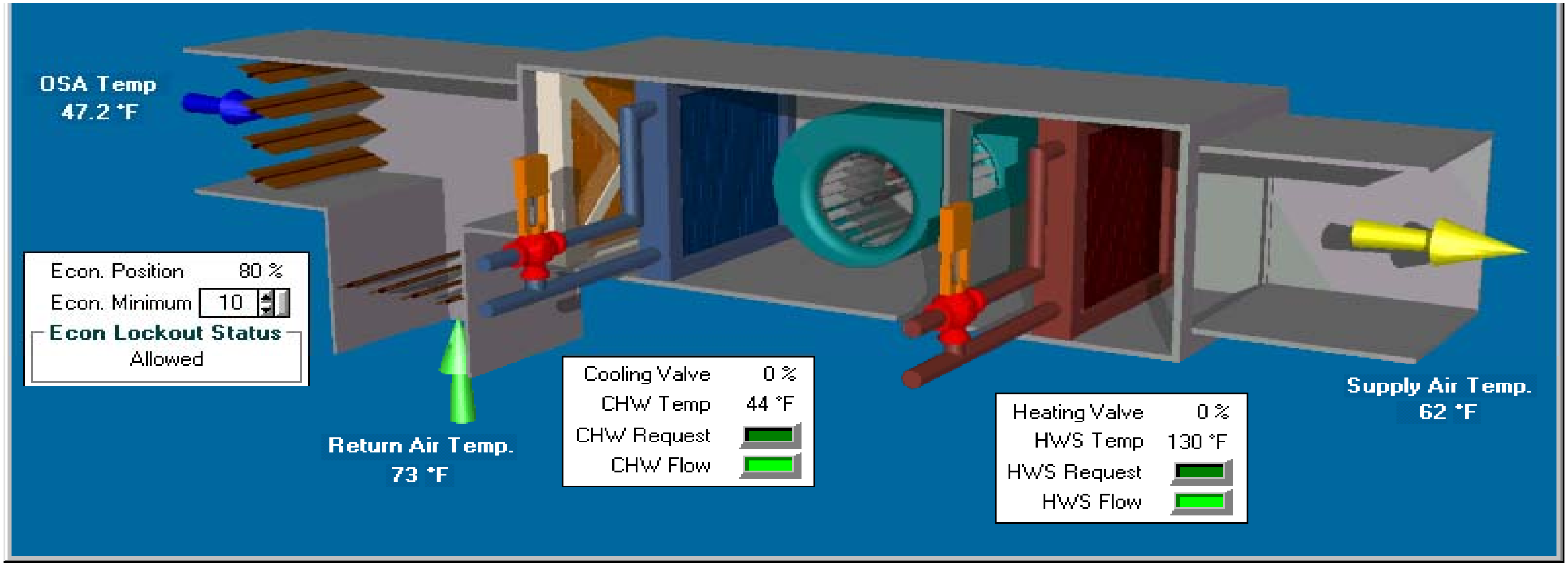
# Minimizing Nuisance Alarms

- Set alarms as low or as high as possible
  - For example, the alarms for a typical room temperature would be set at 78ºF for a high and 65ºF for a low alarm
- Daily repeat alarms should be repaired, not just acknowledged each day.
- Trend alarm points to better track actual conditions
- Re-commission your building annually if alarms or out-of-control conditions consistently occur.

# Trending and Recording Setpoint vs. Control Point

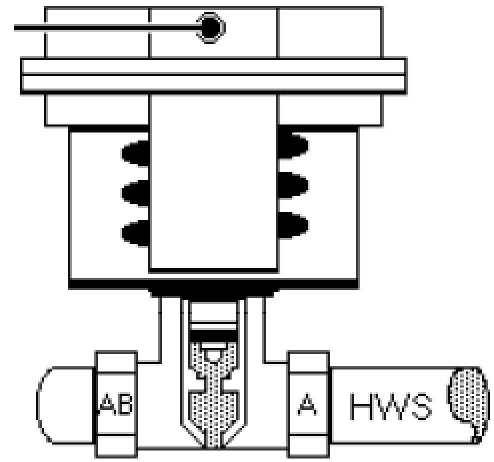
- Use the DDC computer functions for accuracy when making measurements.
- Plot out the DDC control panel and setpoint concurrently to display actual working condition problems.
- Trend temperatures and analog sensors on time, not change of value (COV). Trending on COV is only needed on binary devices.

# Monitoring Graphics




- Monitor dynamic, real world displays, not static graphics
- Look for normal and alarm conditions
- Compare setpoint to control point
- Review discharge air temperature compared to zone demands
- Reset temperatures based on zone requirements

# Calibrating Pneumatics




- Verify actual spring range of the controlled device for calibration
- Cycle controller within spring range
- Control point equals setpoint output during calibration
- Pressure equals middle of spring range

Courtesy TAC Controls/Schneider Electric

# Air Compressor Checkout


- Listen to compressor
- Check runtime length
- Check tank for water
- Check for oil in the water
- Inspect and replace all filters as needed
- Check output pressures at controllers

# Routine Inspection Tips for VAV Boxes and Associated Controls

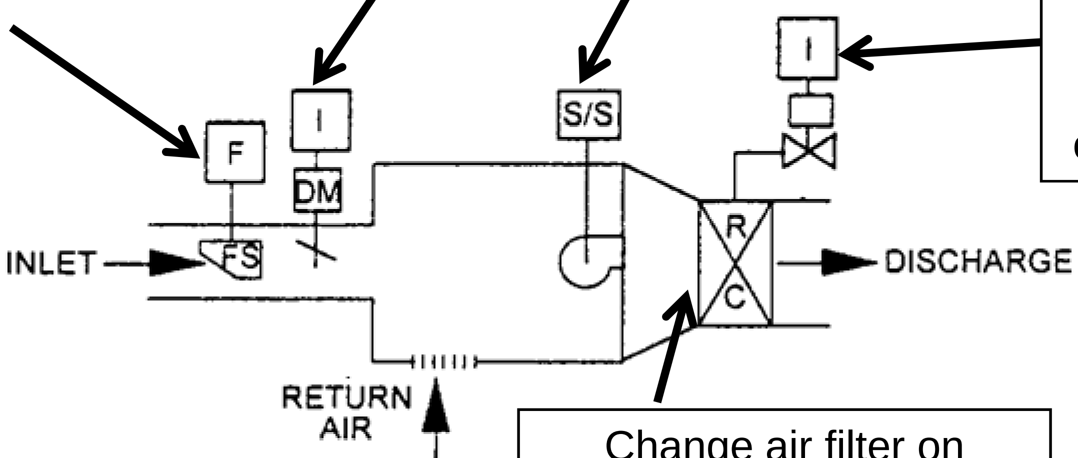
## **Inspect the following parts routinely:**

Check the air flow sensor reading compared to a calibrated instrument

Check the control damper for open-closed operation

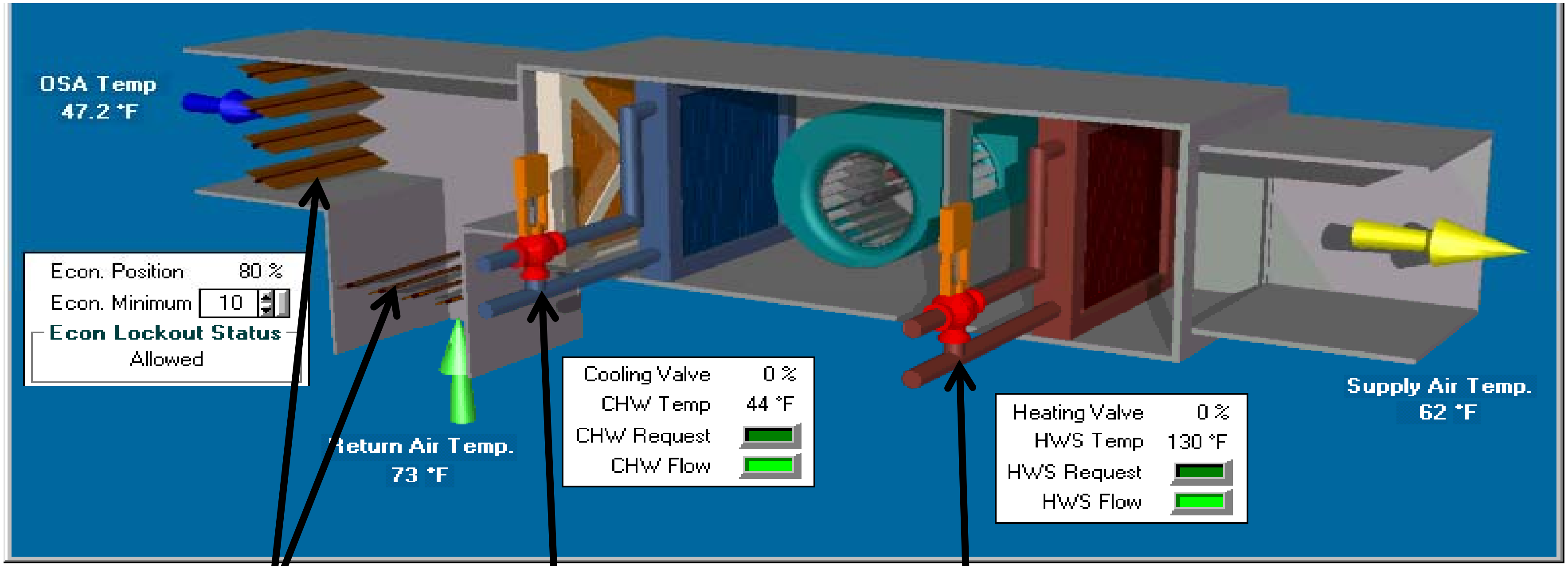
Check the fan operation

Check the control valve for reheat operation




Change air filter on heating coil as needed (when used)

# Routine Inspection Tips for Heating and Cooling Coils on AHU Units

- 


Check the economizer dampers are modulating properly by commanding to 0% and 100%, verify a drop and raise in temperatures as compared to OSA and RA temperatures.

Check the cooling coil valve by commanding to 0% and 100%, verify a drop and raise in temperatures

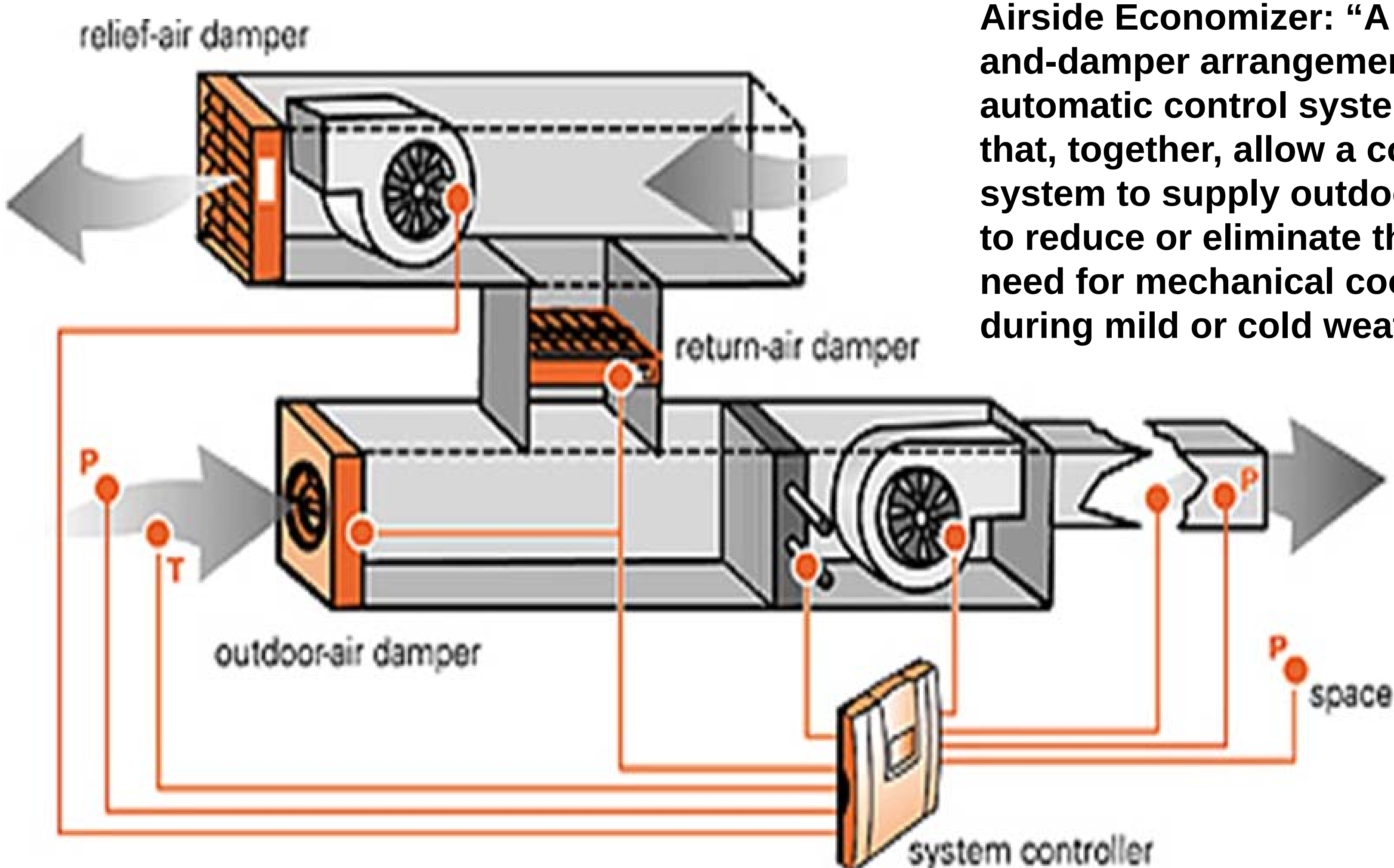
Check the heating coil valve by commanding to 0% and 100%, verify a drop and raise in temperatures

# Calibrating DDC Panels and Control Loops


- Use factory specs for power supply
- Upgrade motherboards within DDC controllers as required to maintain factory support
- Use loop tuning software to adjust software control loops under average loads.
- Adjust one gain at a time
- Seasonal loop calibration may needed
- Calibrate transmitters, transducers etc., against known sources per manufacturer specifications

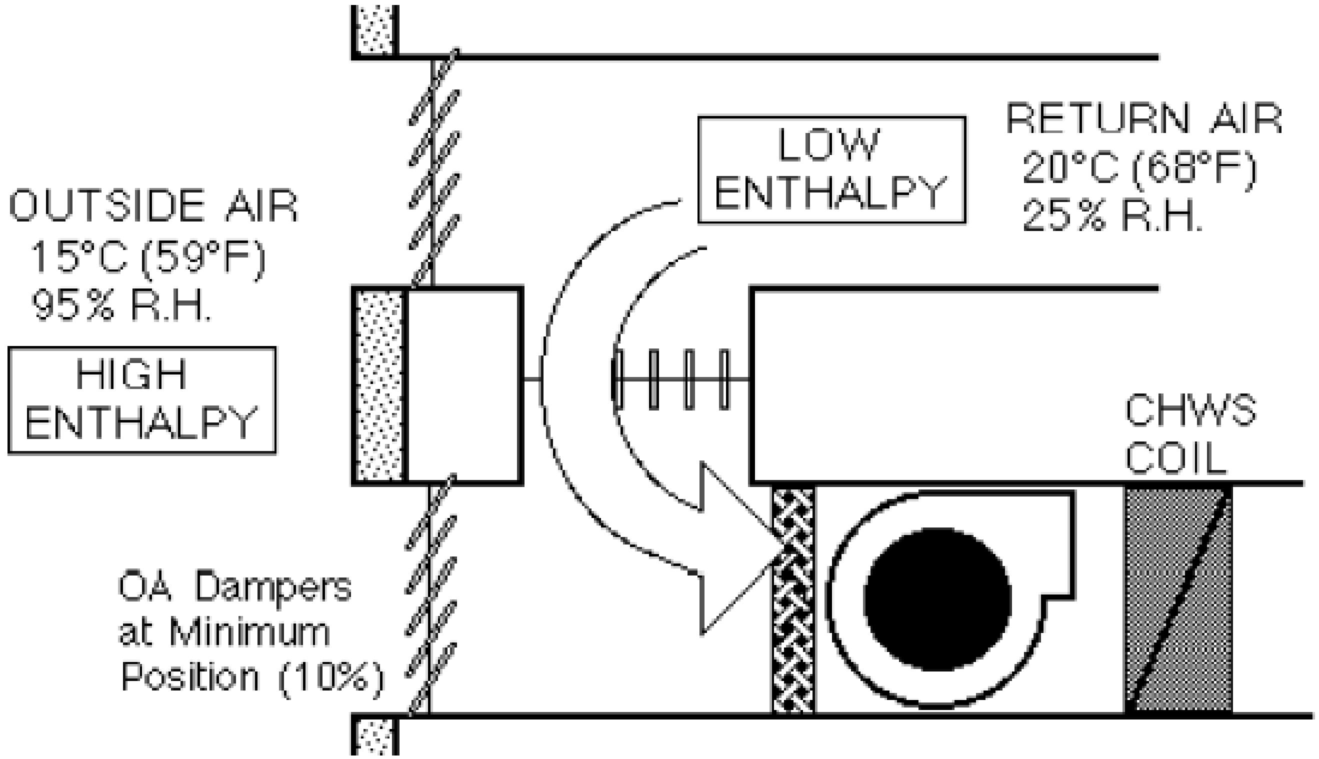
Courtesy Alerton Controls

# Section 7
# Using DDC Controls to Save Energy
## Standard Economizers with Dry Bulb Control




**Airside Economizer: "A duct-and-damper arrangement and automatic control system that, together, allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather."**

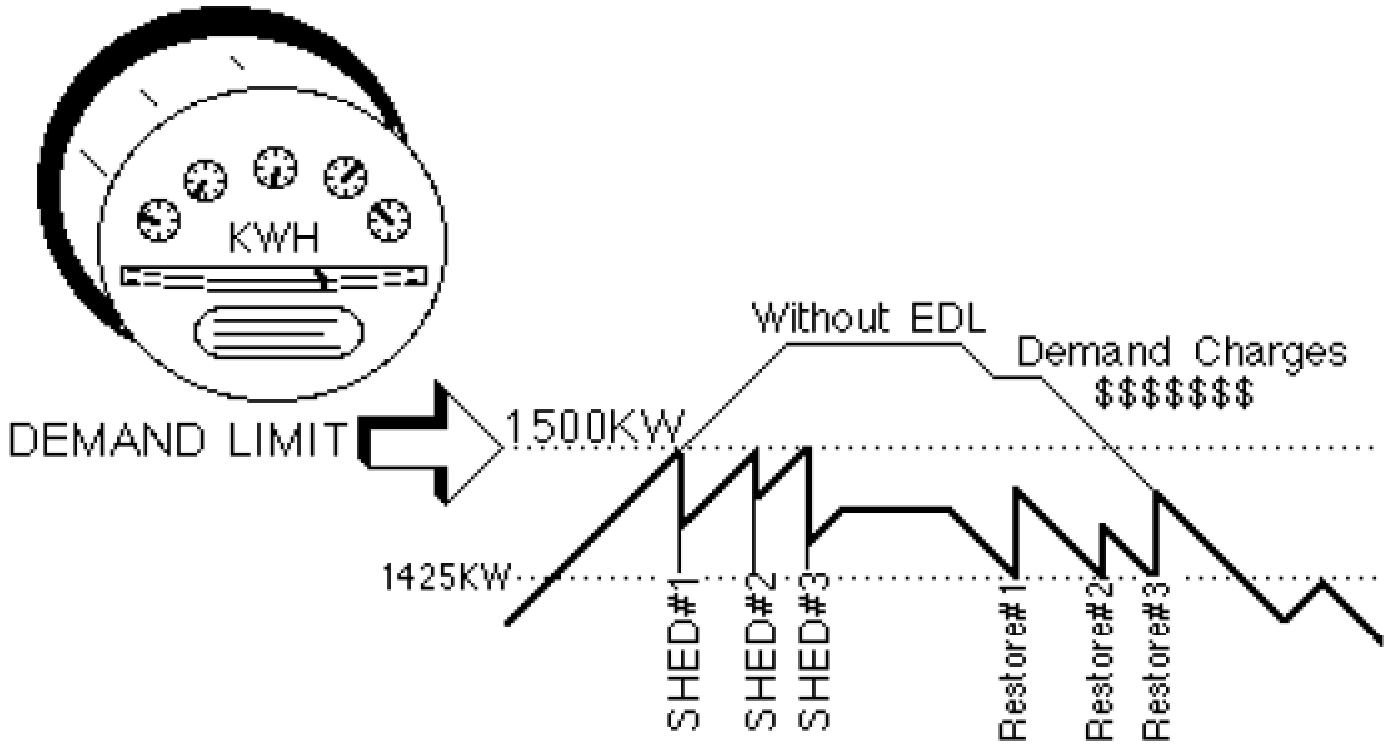
# Using DDC Controls to Save Energy
## with Enthalpy Optimization




Courtesy TAC Controls/Schneider Electric

# Using DDC Controls to Save Energy
## Electric Demand Limiting

Power Demand Limiting is also referred to as EDL.

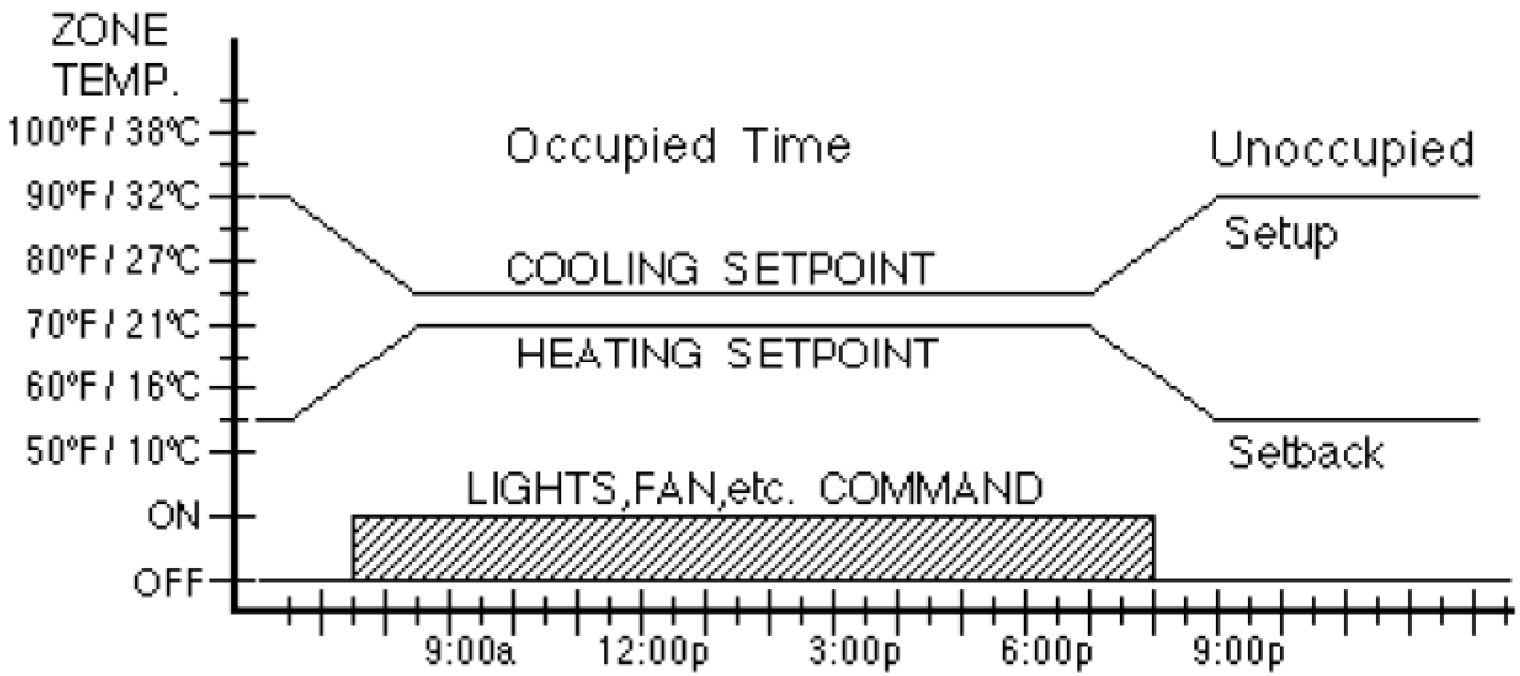



ELECTRIC DEMAND LIMITING (EDL),

Courtesy TAC Controls/Schneider Electric

# Using DDC Controls to Save Energy

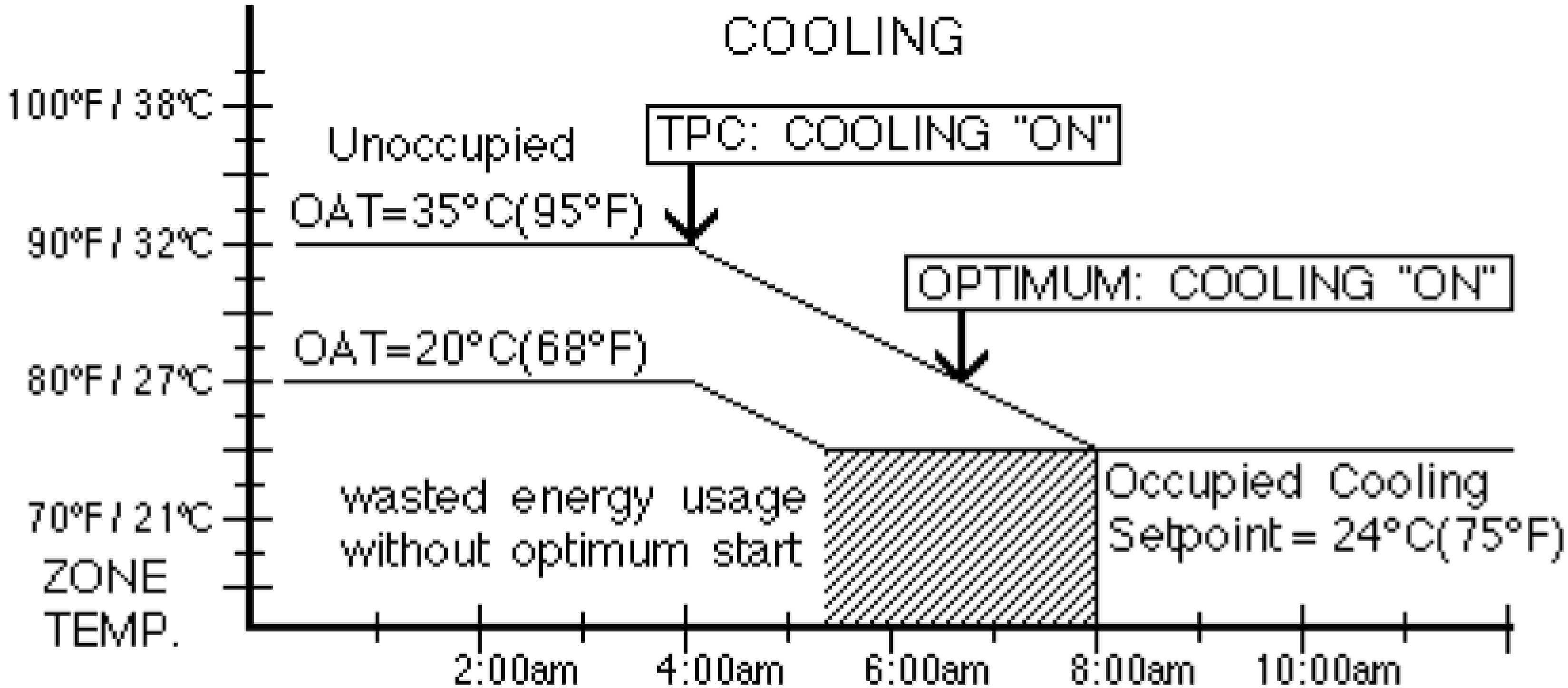
## Time-Programmed Controls




Courtesy TAC Controls/Schneider Electric

# Using DDC Controls to Save Energy

## Optimum Start/Stop




Courtesy TAC Controls/Schneider Electric

# Using DDC Controls to Save Energy
## Getting Back to the Basics

- Are the Pneumatic and DDC Control Systems calibrated?
- Heating and Cooling Simultaneously?
- Sensing Correct Medium Locations?
- Optimum Setpoints
- Sensitivity Adjustments
- System Integration
- Scheduled Preventive Maintenance is a **MUST!**

# Exercise

Fill in the blanks as needed to the following questions

1.) To help minimize alarms on the DDC system, set alarms as _________ or as _________ as possible

2.) Trend temperatures and analog sensors on __________, not ____________ of __________. Trending on _________ is only needed on binary devices.

3.) Upgrade motherboards within DDC controllers as _____________ to maintain ____________ support.

4.) Calibrate transmitters, transducers etc., against ____________sources as per ______________specifications.

# Exercise

1.) T F Air is blown over coils at the air handler in parallel

2.) T F On a VAV fan system, the volume of air delivered is varied using inlet dampers or electronic speed controls based on return duct static pressure setpoint.

3.) T F On a boiler control with outside air reset, the controller automatically changes the supply water temperature set point based on the actual outside air temperature.

4.) T F VAV terminal box units utilize a damper inlet that controls supply air between a 0% closed and a maximum flow rate and include a reheat coil and control valve.

5.) T F Airside economizers simply utilize air source energy from inside the building to cool the building or to supplement the mechanical cooling system.

6.) T F The optimum start program computes the optimum time to start the heating or cooling equipment so that at the precise beginning of occupied time, the zone is at the desired temperature.