

## System Diagram Workshop

## **Basic Principles**



Presented By: David Sellers Senior Engineer, Facility Dynamics Engineering

## **Resource for Details Behind this Content**

www.Av8rdas.Wordpress.com

Posts with the heading "System Diagrams: ..."



http://en.wikipedia.org/wiki/Piping and instrumentation diagram - From the author's own work - Creative Commons Share Alike

## **Starting Points for Symbols**

### ISA-5.1-1984 Instrumentation Symbols and Identification

6.6 Symbols for self-actuated regulators, valves, and other devices (contd.)



The scienicd-tripped pressure relief valve is one of the class of poweractuated relief valves and is grouped with the other types of relief valves even though it is not entirely a self-actuated device,

## **Starting Points for Symbols**

2009 (or earlier) ASHRAE Handbook of Fundamentals, Chapter 37



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ay butterfly control valve - electric.dwg

2 way butterfly control valve.dwa

🖬 2 way valve with manual over ride.bak

🔁 2 way valve with manual over ride.dwg

12-07-07 Simple Flow Diagram Symbols.zip

🧏 3 way butterfly control valve.dwg

2 way reheat coil.dwg

💐 3 way reheat coil.dwg

a way valve.dwg

3 way valve bak

3 way valve.dwg

### Points for Symbols File Edit 🤇 Back 👻 Address C:\Documents and :

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### Details Simple Flow Diagram

Symbols File Folder Date Modified: Thursday. September 02, 2010, 7:16 AM

\*

Your Own Creativity 🖬 Auto air vent.bak Auto air vent.dwg Automatic air vent with service valve.dwg 🖲 Back pressure regulator.dwg 🖲 Balance valve.dwg Ball valve - instrument.dwg Ball valve- hydraulically actuated.bak 🔏 Ball valve- hydraulically actuated.dwg Ball valve.dwg Barometric damper.dwg Basket Strainer.dwg 🖲 Break HHWR.dwg Break HHW S.dwa 🖲 Break.dwg Butterfly valve - small.dwg Butterfly valve.dwg Ceiling diffusser.dwg Ceiling.dwg 🖬 Centrifugal Seperator.bak Centrifugal Seperator.dwg Check valve bak Check valve.dwg Chilled water coil with 2 way valve.bak Chiller - Modular.dwg Chiller with Auto Iso VIv and Bypass.bak Chiller with Auto Iso VIv and Bypass.dwg Chiller.dwg Concentric reducer.dwg Condensing Boiler.dwg Conductivity Sensor.dwg Control - Averaging temperature.dwg Control - Combination duct temp and humidity.dwg Control - Differential pressure sensor.dwg Control - Diffrential pressure.dwg Control - Duct Humidity.dwo Control - Freezestat.bak Control - Insertion temperature.dwg Control - Limit switch.dwg 🧟 Control - Make up meter.dwg 🖬 Control - Space humidity.bak Control - Space humidity.dwg Control - Space tempertaure.bak Control - Space tempertaure.dwg

Control - Surface Temperature Sensor - Horizontal.dwg

Control - Surface temperature sensor.dwg

Control - Switch bak Control - Switch dwo Control - Temperature sensor with well - Vertical.dwg 🖬 Control - Temperature sensor with well.bak Control - Temperature sensor with well.dwg Control - Turbine flow meter 1.dwg Control - Turbine flow meter.dwg Controls - Air Flow.dwg Controls - Averaging tempertaure sensor.bak Controls - Averaging tempertaure sensor.dwg Controls - Current relay.dwg ontrols - Filter DP.dwa

#### control points - No Fire.bak Controls - Starter or VFD with control points - No Fire.dwg Controls - Starter or VFD with control points.dwg Controls - Starter or VFD.dwg Cooling Tower Additional Cell.bak Cooling Tower Additional Cell.dwg Cooling Tower Base Cell.bak Cooling Tower Base Cell.dwg Cooling Tower Make Up Set Up - Float.bak Cooling Tower Make Up Set Up - Float.dwg Cooling Tower Single Cell.dwg Coolina tower.dwa Damper - vertical - manual.dwg damper actuator.dwg Differential pressure switch.dwg 🖲 Double break line.dwg 💐 Drain.dwg DX Coil with Hot Gas Bypass.bak DX Coil with Hot Gas Bypass.dwg Ecentric reducer.dwg Economizer section - No MOA - Opposed blade.bak Economizer section.dwg Electric Heating Coil.dwg Enthalpy wheel.dwg Evaporative cooler.dwg Expansion Loop.dwg Expansion tank diaphram type.dwg Expansion tank open type.dwg Face and bypass damper.dwg 🖬 Fan Powered Terminal Unit - Series.bak 🦄 Fan Powered Terminal Unit - Series.dwg Fan.dwg 🖲 Final Filter.dwg 🖣 Flange Cap Right.dwg Flex.dwg Float Valve.dwo 🖲 FloSet Strainer.dwg 🖲 FloSet Union.dwg Flo Set valve.dwg Flow arrow - curved.dwa 🦄 Flow arrow - straight.dwg 🦰 Flow arrow.dwg 🖲 Flow control valve.dwg Flow meter - Annubar Type.dwg Flow meter - Turbine.dwg

Flow Switch.bak

EDTLL, Darallel dura FTR Element - No Valve.dwg Gate valve - small.dwg Gate Valve.dwg Gauge and gauge cock.dwg Gauge cock.dwg Gauge with cock.dwg Gauge.bak 🖬 Horizontal damper bak Horizontal damper.dwg 🖲 Hot water coil - 2 way valve - pumped.dwg d Hot water coil with 2 way valve.bak Hot water coil with 2 way valve dwa Hot water coil with 3 way valve.dwg 🔲 Humidifier - Trim.bak 🗟 Humidifier with shut-off bak Humidifier with shut-off.dwg 🖲 Humidifier.dwa In Line Pump Strainer Ball Valves Check Valve.dwg Increaser.dwg Injection fitting.dwg Instrumentation Valve.dwg Jet diffusser box.dwg 🗟 Ladder - Feed thru terminal.dwa Ladder - Fused terminal.dwg Ladder - Grounding terminal.dwg Ladder - NO Contact.dwg 💐 Ladder - Switch terminal.dwg 🖲 Line size bottom.dwg 🖲 Line size right.dwg 🖬 Load or equipment block.bak Load or equipment block.dwg 🖬 Load with 2-way valve.bak Load with 2-way valve.dwg 🖲 Load with 3 way valve.dwg Louver.dwa 🗟 Make up meter bak Make up meter.dwa 🖲 Mechanical Coupling.dwg Needle Valve.dwg new block.dwg Node Number Left Bottom.dwg 🖲 Node Number Left Top.dwg 🗟 Node Number Right Bottom.dwg Node Number Right Top.dwg 🖲 NYMEX AHU CHW Coil Bank.dwg 🖲 One break line.dwg 🖬 Petes plug.bak 🆣 Petes plug.dwg 🖬 Pipe size leader.bak Dine size leader dwo Relate and Frame Heat Exchanger with Auto Iso Valve.dwg 🗐 plot.log 🖣 Plug Valve.dwg Prefilter with Bag Filter.dwg Prefilter with final filter.dwg 🖲 Pre-filters.dwg Rressure - temperature test port.dwg Pressure reducing valve.dwg 🧃 Pressure relief door - Labeled.dwg

🖥 EPTU - Parallel bak

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Pump - ball valve suction diffusser check.dwg Pump DP Switch.dwg 🖬 Pump Gauge Set (no strainer).bak 🎘 Pump Gauge Set (no strainer).dwg 🦉 Pump Gauge Set (with strainer).dwg Pump set with 2 BF Strainer Flex and Check.bak Pump set with 2 BF Strainer Flex and Check.dwg Rump set with SD Flex and TDV.dwg Pump times 2.dwg Pump with 2 BF mech flex and check no note.dwg Bump with 2 BF mech flex and check.bak Pump with 2 BFs check and flex.dwg Rump with check and 2 butterfly valves.dwg Rump with check service and plug valve.dwg Pump with check valve bak Pump with check valve dwg Pumped Preheat Coil.dwg Radiant panel.dwg RAG with filter.dwg Reheat coil with 2way valve.dwg 🖲 Riser - Conduit Body.dwg Riser - Junction Box.dwo 🖲 Roll up garage door.dwg 🖲 Ron's Valve.dwg SEN\_2WCV.DWG SEN 3WCV DWG SEN\_CRLY.DWG SEN DMPA.DWG SEN\_DP.DWG SEN\_FISD.DWG SEN\_SMKD.DWG SEN STRT.DWG SEN\_TAV.DWG Sensor - Air Flow.bak
Sensor - Averaging temperature.bak Sensor - Duct Humidity.bak 🖲 Shot feeder.dwg Size lead - Horizontal - Bottom.bak Size lead - Horizontal - Bottom.dwg 🖬 Size lead - Hosizontal - Top bak 🚆 Size lead - Horizontal - Top.dwg 🖬 Size lead - Vertical - Left.bak 🎘 Size lead - Vertical - Left.dwg 🖬 Size lead - Vertical - Right.bak 🎦 Size lead - Vertical - Right.dwg Steam Heat Exchanger.bak Steam Heat Exchanger.dwg Strainer with blow down.dwg

Suction Diffusser - 90.dwg 🔟 Suction diffusser.bak Suction diffusser.dwg Sump pump with check valve.dwg Tank.dwa Temperature transmitter with calibration thermometer.dwg Temperature transmitter with calibration well.dwg Temperature transmitter dwo 🖬 Thermometer well.bak Thermometer well.dwo 🖄 Thermometer with 2nd well.dwg Thermometer.bak Thermometer.dwg Three way valve dwa Triple duty valve.dwg Turbine Flow Meter.dwg 🖣 TurFl.dwg Two way valve.dwa Typical pump assembly dwg Typical Zone.dwg 🖣 Union dwo UV Array.dwg 🖲 Vane meter.dwg VAV reheat terminal with two way hot water coil.bak VAV reheat terminal with two way hot water coil.dwg 🖲 Vent.dwg 🖲 Vertical damper medium.dwg 🍓 Vertical damper small.dwg 🖲 Vertical damper.dwg Vertical opposed blade damper - closed.dwa Vertical opposed blade damper - open.dwg Vertical opposed blade damper with actuator - short.dwa Vertical opposed blade damper with actuator.dwg VFD.dwg Victaulic Flex.dwg

🍯 Water Meter.dwg

Strainer.dwg

Zone damper.dwg

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## A Ladder On Its Side in Japanese

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Yoko ni hashigo no yō ni

We're doing that Japan training this week .... Just thought you'd want to know that the phrase "Ladder on its side" has officially been translated into another language!!

**Brian Clark** 

Mechanical Engineer, Energy Branch Construction Engineering Research Laboratory US Corps of Engineers Former EBCx Workshop Student

## Dealing With a Ladder On Its Side "On



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## Dealing With a Ladder On Its Side "On



NCEPTS

Revisions: 2 - 1-24-02 - Modified arrangement of factory piping to make it dearer	
Revisions: 3 - 12-15-03 - Updated and detailed to include radiant panel heat exchanger and HP12.	
Revisions: 4-Release 3/23/04	BASIC CO





# What's on the Ladder Rungs and What's on the Ladder Rails Can Vary

## "What's using up the pump head?" focus

## "What's making and using cold glycol?" focus





## "Untangled" versus "Tangled"



tangled adj

- 1. existing in or giving the appearance of a state of utter disorder
- 2. very involved : exceedingly complex

## "Untangled" versus "Tangled"

Tangled

### Untangled



## "Untangled" versus "Tangled"

Keep simplifying things to minimize line crossings and head towards a "ladder on its side"

But remember:

*Things should be made as simple as possible, but not any simpler. Albert Einstein* 

That means for a system diagram, order of connection "trumps" untangled



## Schematics; Another Common Tool



# An Exercise Applying What You've Learned So Far

- Half the class take the piping plan in the next slide and make a system diagram from it
- The other half of the class take the schematic in the previous slide and make a system diagram from it
- See if there are any problems that jump out at you from your system diagrams
- Did you recognize/understand them before you did the system diagram?







## See Any Problems







## A Recent Field Experience http://tinyurl.com/2023-09-20CHWPumpConnection



🔄 Jess's CHW Pump Click here for the field sketch of the CHW system diagram Yellow dots are spherical panoramas

## **Order of Connection Matters**



## Getting Ready to Go Out in the Field

Study existing drawings if they exist

- May include a schematic
- May reveal issues
- Provides a first draft
- Be ready for reality
- Clipboard
- Paper
- Flashlight
- Camera



## **Getting Started**

Find something you can identify

- Nameplate data
- Labels
- Past experience



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Start following the system of interest

 Your first effort will likely not be your last effort

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- Your first effort will likely not be your last effort
- "Follow your nose"



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• Identify a Point of Reference



• Identify a Point of Reference



- Identify a Point of Reference
- Identify Your "Pace"
- Use Your "Pace" to Develop Coordinates Relative to the Point of Reference



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- Identify a Point of Reference
- Identify Your "Pace"
- Use Your "Pace" to Develop Coordinates Relative to the Point of Reference
- Apply Your Coordinates on a Different Floor
- Leverage Existing Labels (Maybe)
  - Cutting a hole in the wall or shaft may or may not be warranted
  - Leverage other clues
  - Some of them may be misleading



#### What About Drawing Programs?

#### AutoCAD and AutoCAD LT

- Quasi-standard in the industry
- Full version \$3 \$4K
- Factor of 4 price difference between full and LT version
- LT probably sufficient for most Cx providers
- Steep learning curve
- Can do more than diagrams
  - Drafting
  - Some 3-D
  - Automation

#### Visio

- Microsoft family
- Full version about \$1K
- Factor of 4 price difference between low end and high end versions
- Geared toward diagrams
  - Not as universally applicable
  - Faster to pick up
- Basic wire-frame capabilities in higher end products
- Interfaces with other Microsoft products directly

#### What About Drawing Programs?

Draw – OpenOffice.org

- Free
- Limited page size (about 12" x 12")
- Basic diagramming features
- 3D capabilities

Word/PowerPoint Drawing Utilities

- Part of the Office package
- Difficult to use for complex drawings
- Relatively easy to pick up for basic shapes
- Some issues with alignment in 2007 versions

#### What About Drawing Programs?

#### Sketch-up

- Google/Trimble
- Free
- Using 3D model to convey 2D information



Get in the habit of drawing on a grid

- "Electronic graph paper"
- Orderly drawings
- Alignment is easier
- Can be "on" or "off" for printing



#### **Colors can be used to advantage**

- Distinguish different types of fluids (chilled water, hot water, condenser water)
- Distinguish hot from cold, warmer from cooler, supply from return



#### **Colors can be used to advantage**

- Distinguish different types of fluids (chilled water, hot water, condenser water)
- Distinguish hot from cold, warmer from cooler, supply from return
- Enhance understanding Outside Air mixing with Return Air makes Mixed Air

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Line weights can be important



Line weights can be important

- Heavier lines draw the eye towards the major system elements
- Lighter line weights show related equipment that is auxiliary to the main system elements



Points where lines cross vs. connect should be clear

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Points where lines cross vs. connect should be clear

 Gaps where lines cross need to consider the plot scale relative to the line weight



Points where lines cross vs. connect should be clear

- Gaps where lines cross need to consider the plot scale relative to the line weight
- "Bumps" can be used to clarify line crossings but can become tedious to draw

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Create symbols

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- This data can then be extrapolated to generate equipment schedules, point lists, etc.



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- AutoCAD blocks are an example
- AutoCAD allows you to assign "fill in the blank" field for data associated with the block
- This data can then be extrapolated to generate equipment schedules, point lists, etc.
- You can also edit blocks after they are inserted

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#### Desirable habits/features

- Frequent "saves"
- Enable "auto-save"
- Regular back-ups

toCAD LT	
AD LT has encountered an error and must shut down. We any inconvenience this may have caused.	
#### Tee's are Important

For both the physical system and the system diagram:

- Divergence or convergence of flow
- An opportunity to introduce a problem if the order of connection is not correct

For the physical system, they represent a pressure drop

- Significant
- Highly variable with configuration



#### Notes:

1. Chart is based on straight tees (i.e., branches A, B, and C are the same size).

2. Pressure loss in desired circuit is obtained by selecting the proper curve according to illustrations, determining the flow at the circled branch, and multiplying the pressure loss for the same size elbow at the flow rate in the circled branch by the equivalent elbows indicated. 3. When the size of an outlet is reduced, the equivalent elbows shown in the chart do not apply. Therefore, the maximum loss for any circuit for any flow will not exceed 2 elbow equivalents at the maximum flow occurring in any branch of the tee.

- Top curve is average of 4 curves, one for each circuit shown.
- BASIC CONCEPTS. Data from Giesecke and Badgett 1931, 1932.

From the perspective of the system diagram:

- Just a bent piece of straight pipe
- Water in = Water out





One way to think of elbow resistance is to consider it as composed of:

Resistance due to interaction with the pipe wall

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#### Total Resistance for the Elbow

BASIC CONCEPTS

From the perspective of the physical system:

- Pump energy required
- Long radius = optimized loss = energy savings





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+ Resistance due to a change in direction

#### Total Resistance for the Elbow

BASIC CONCEPTS

## System Diagram Rules for Elbows and Tees

#### Show all tees

- Verify order of connection
- Order of connection "trumps" drawing organization
- Drawing organization "trumps" matching branch and main configuration in the field
- Don't show elbows
- Turns on the system diagram should be made for drawing organization purposes, not to reflect real elbows

#### Sometimes Rules are Made to be Broken

Elbows that form traps or inverted traps in open systems Pipes that run above basin level in open systems Pipe runs with an relatively excessive number of elbows Tees where the pressure drop created by the installed configuration could cause an operational issue

# So Far, Our Focus Has Been Hydronic Systems; What About Air Systems?

## Can You Identify the HVAC/Air Handling System Elements in this Picture?

TO

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### Air Handling Systems and System Diagrams

The same general rules apply Significant differences from piping systems

- Envelope is a part of the system
- Mass (air and water vapor) are actively moved across the system boundary by the operation of the system
- The water vapor can change state in the system
- People move around inside the systems
- Building processes occur inside the system



## Envelope Integrity = Process Integrity = Cash Flow Integrity



### **A Demonstration of Fundamental Principles**



#### Conservation of Mass; A.K.A The Goes Intas gotta equal the Goes Outa's



#### The Envelope is Significant(I)



## The Envelope is Significantly Complex



## The Envelope is Significantly Complex



## The Envelope is Significantly Complex







**BASIC CONCEPTS** 





#### Typical Public Lobby Area (Served Direct/Indirect Evaporative Cooled AHU)



#### BASIC CONCEPTS







#### **Air Handling System Diagram Characteristics**



#### **Reflect the Building Physical Arrangement**



#### Include Examples of Each Zone Type



#### Include the Impacts of Other Systems





### Let's Try Applying What We've Learned

