WaterFurnace®

Commercial Solutions Group

National and Local Attention

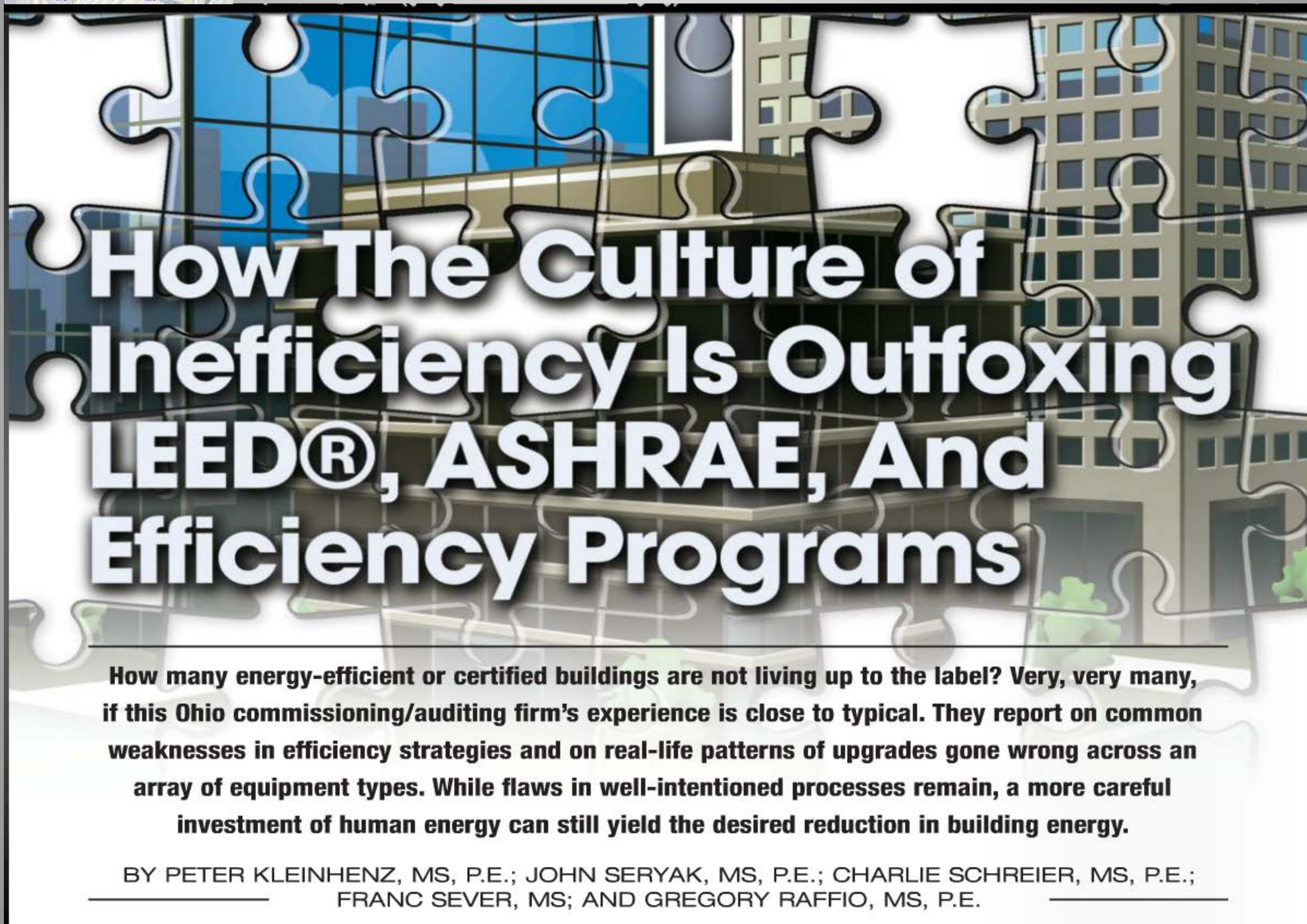
- Energy Use and Water Use
- DOE - Building Performance Database
  - Location
  - Type of building
  - Size and function
  - SYSTEM
- Energy Star – Portfolio Manager
- Measurement and Verification

Fundamental Change!

If nothing changes – how can you get new results?

- Release Creativity
  - Application knowledge
  - Code
  - Contracts
- Team versus – "low bid!"
  - Buy everyone's mistakes
  - Projects too complex to maintain
    - Artificial efficiency
    - Modeling accuracy

EER vs. SEER vs. IEER



How The Culture of Inefficiency Is Outfoxing LEED®, ASHRAE, And Efficiency Programs

How many energy-efficient or certified buildings are not living up to the label? Very, very many, if this Ohio commissioning/auditing firm's experience is close to typical. They report on common weaknesses in efficiency strategies and on real-life patterns of upgrades gone wrong across an array of equipment types. While flaws in well-intentioned processes remain, a more careful investment of human energy can still yield the desired reduction in building energy.

BY PETER KLEINHENZ, MS, P.E.; JOHN SERYAK, MS, P.E.; CHARLIE SCHREIER, MS, P.E.; FRANC SEVER, MS; AND GREGORY RAFFIO, MS, P.E.

Know what you want

EER

IEER

	Cooling				High Heating 47 F		Low Heating 17 F		Heating
Indoor Type	Capacity (Btuh)	EER	IEER	SCHE	Capacity (Btuh)	COP	Capacity (Btuh)	COP	Capacity (Btuh)
Ducted Indoor Units	114000	11.30	16.10	15.30	129000	3.40	87000	2.35	
Non-Ducted Indoor Units	114000	12.10	21.30	19.60	129000	3.60	87000	2.60	
Ducted Indoor Units	114000	11.30	16.10	15.30	129000	3.40	87000	2.35	
Non-Ducted Indoor Units	114000	12.10	21.30	19.60	129000	3.60	87000	2.60	
Ducted Indoor Units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.40	104000	2.40	
Non-Ducted Indoor Units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.60	104000	2.55	
Ducted Indoor Units	138000	13.70	20.00	16.00	154000	3.60	104000	2.40	

12.1 versus 21.3

IEER

- Room air at 80/67

- 2% at 100% unit capacity
- Plus part load conditions, OA temp and load
  - 61.7% at 75%
  - 23.8% at 50%
  - 12.5% at 25%
- Do Not use this in combination with Bin Data

Fundamental Change!

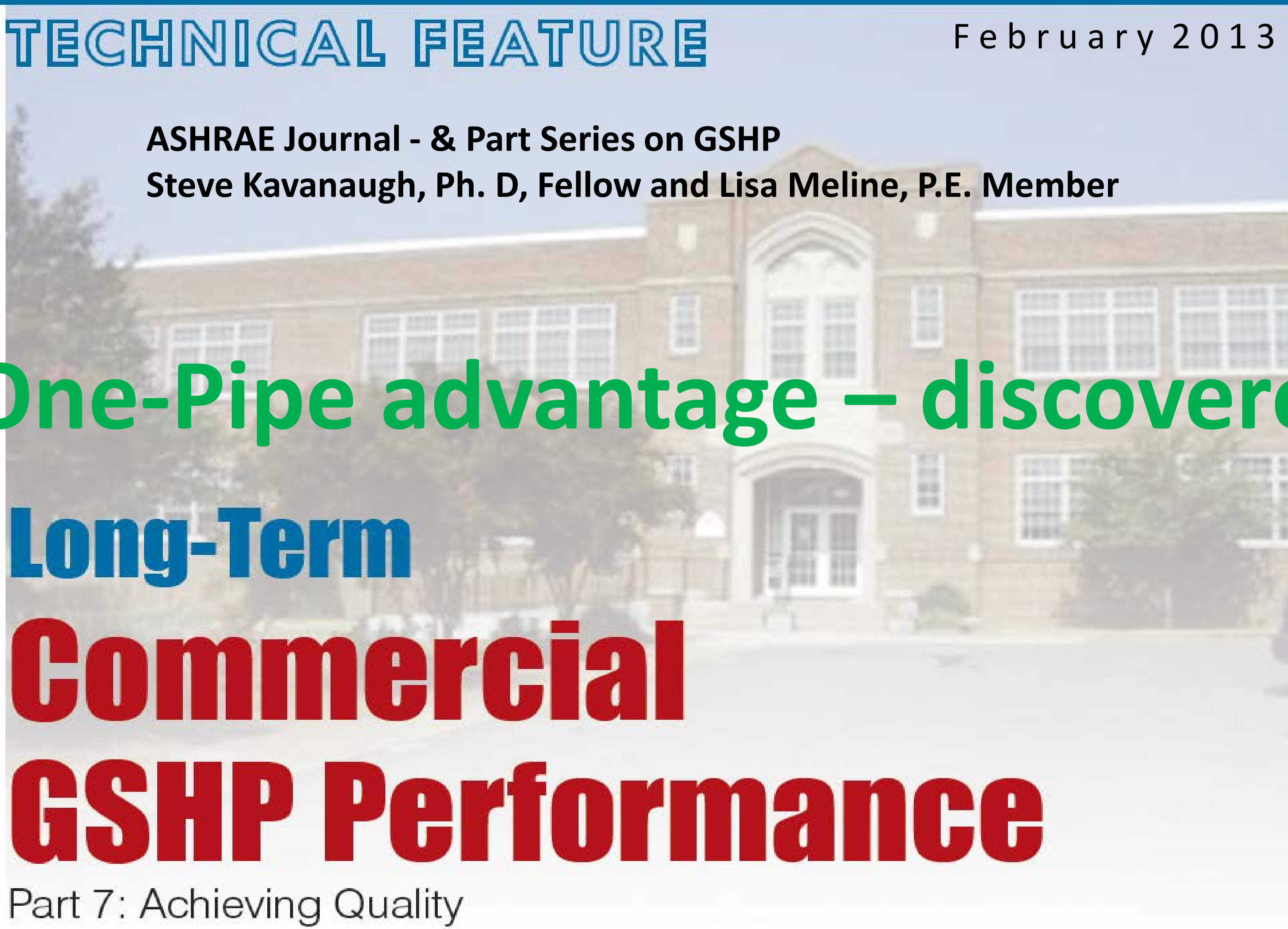
If nothing changes – how can you get new results?

- Release Creativity
  - Application knowledge
  - Code
  - Contracts
- Team versus – “low bid!”
  - Buy everyone’s mistakes
  - **Projects too complex to maintain**

February 2013

ASHRAE Journal - & Part Series on GSHP

Steve Kavanaugh, Ph. D, Fellow and Lisa Meline, P.E. Member



One-Pipe advantage – discovered

Long-Term Commercial GSHP Performance

Part 7: Achieving Quality

By **Steve Kavanaugh, Ph.D.,** Fellow ASHRAE; **Lisa Meline, P.E.,** Member ASHRAE

This is the final installment in a series that summarizes a data collection and analysis project to identify common characteristics of

ers, contractors, and owners are unwilling to share results.

• Designers, contractors, and owners

Systems with heat pumps circuited to individual ground loops, small central, or multiple common loop circuits out-performed systems with large central loop circuits by a significant margin.

Why are we going to talk 1x4-pipe?

Characteristics of Successful GSHPs

- The ENERGY STAR rating of the building exceeds 90.
- Maximum loop temperatures returning from the ground tend to be below 90°F (32°C) for systems in which the cooling mode determines loop length.
- The systems surveyed during this project were primarily 10-month schools and 8 a.m. to 5 p.m. offices located in areas where the measured ground thermal conductivity was between 1.0 and 1.5 Btu/h·ft·°F (1.7 and 2.6 W/m·°C). Under these circumstances, the successful vertical ground loops tend to be in the range of 200 to 240 ft of vertical bore per installed ton (17 to 21 m/kW) of cooling capacity for a ground temperature of 63°F (17°C). This corresponds to a range of 155 to 185 ft per ton (13 to 16 m/kW) for 55°F (13°C) ground temperature and 270 to 320 ft per ton (23 to 28 m/kW) for 70°F (21°C) ground.
- The ground loop lengths of systems in this survey were all dictated by the cooling mode requirements. This resulted in advantageous heating mode ground loop temperatures even at the coldest sites in Central Illinois. At the one site that was monitored continuously, the ground loop return temperature remained above 46°F when the outdoor temperature was –6°F (–21°C).
- The primary equipment type tends to be water-to-air heat pumps.
- Installed outdoor ventilation air equipment capacity tends to be 20 cfm/person (9.4 L/s per person) or less.
- Systems with heat pumps circuited to individual ground loops, small central, or multiple common loop circuits out-performed systems with large central loop circuits by a significant margin.
- Pump control tends to be on-off for these smaller loop circuits rather than variable speed.
- Ground loop pump power tends to not exceed 10 hp/100 tons ($kW_{Pump}/kW_{HeatPump}$). This value is deemed to be average (Grade = C) using recommended guidelines.[7]
- Due to the selection of piping materials and pH level of the fill water, piping systems tend to not require chemical treatment. However, caution is advised against using PVC pipe. It is not recommended for service when contact with polyolester oil is possible[8] if leaks occur in the water coils of HFC-refrigerant systems.
- Control is provided by individual thermostats or a building automation system that is simple with a clear and concise sequence of operation so program adjustments (or retrocommissioning) can be performed by the maintenance staff.
- When surveyed, occupants rate indoor comfort, indoor air quality, acoustics, lighting, maintenance responsiveness, and system controllability as satisfactory.
- When surveyed, the maintenance staff rates system serviceability, quality of design, and quality of installation as satisfactory.
- Owners and designers are satisfied with utility cost and they openly share results (and permit ENERGY STAR rating).
- Owners and designers are satisfied with the installation costs, they will openly share itemized results, and they are confident the project provides positive economic value.

All of these Schools expanded the One-Pipe concept to GeoExchange

System
$/sq. ft.
8.82
to
19.45

Loop
$/sq. ft.
4.41
To
6.64
Or
$/ton
2178
Avg.

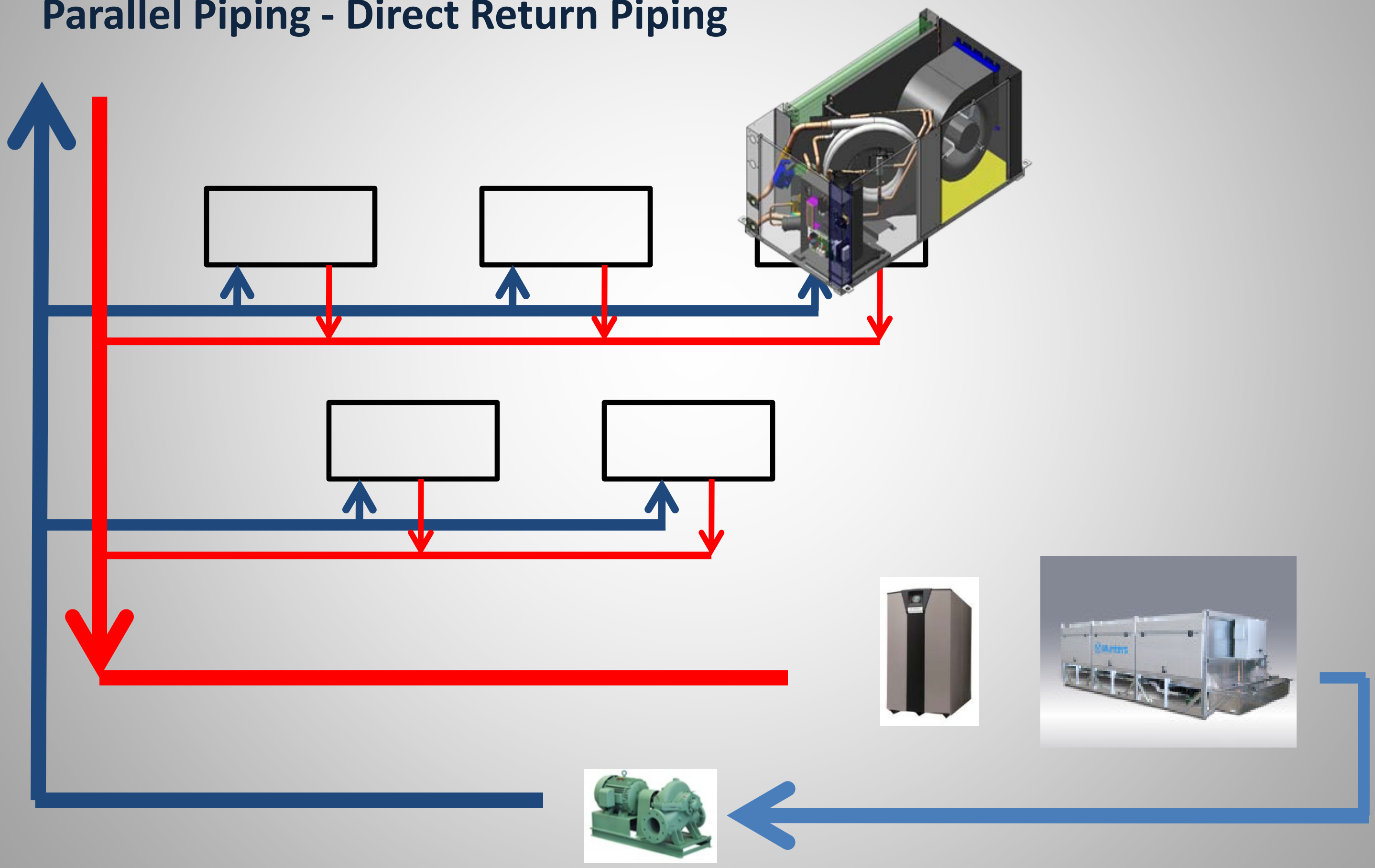
Building Type	Elementary School	Elementary School	Elementary School	Elementary School	Elementary School	Elementary School	Elementary School
Installation Type	Retrofit	Retrofit	Retrofit	Retrofit	Retrofit	Retrofit	New
GSHP Installation Date	2006	2006	2007	2007	2008	2008	2010
Building Construction Date	1954	1954	1957	1954	1938	1956	2010
Building size (ft^2)	23,700	43,200	37,400	31,000	19,000	55,150	76,900
Equipment Capacity (tons)	59	115	86	67	48	117	218
GSHP System ($)	$490,000	$859,000	$621,000	$499,000	$390,000	$736,000	$2,007,000
GSHP System ($/ton)	$8,305	$7,470	$7,221	$7,448	$8,125	$6,291	$9,206
GSHP System ($/$ft^2$)	$20.68	$19.88	$16.60	$16.10	$20.53	$13.35	$26.10
Ground Loop ($)	$123,000	$225,000	$195,000	$156,000	$105,000	$243,000	$511,000
Ground Loop ($/ton)	$2,085	$1,957	$2,267	$2,328	$2,188	$2,077	$2,344
Ground Loop ($/$ft^2$)	$5.19	$5.21	$5.21	$5.03	$5.53	$4.41	$6.64
Ground Loop ($/ft)	$12.30	$12.23	$13.00	$13.00	$13.13	$13.50	$13.10
Vertical Bore Length (ft)	10,000	18,400	15,000	12,000	8,000	18,000	39,000
Vertical Bore (ft/ton)	169	160	174	179	167	154	179
Vert. Bore ($)	$82,000	n/a	$129,000	$98,000	$72,000	$144,000	n/a
Vert. Bore ($/$ft^2$)	$3.46	n/a	$3.45	$3.16	$3.79	$2.61	n/a
Vert. Bore ($/ft)	$8.20	n/a	$8.60	$8.17	$9.00	$8.00	n/a
Exterior Header & Purge ($)	$40,000	n/a	$66,000	$59,000	$33,000	$99,000	n/a
Header & Purge ($/$ft^2$)	$1.69	n/a	$1.76	$1.90	$1.74	$1.80	n/a
HVAC System ($)	$367,000	$634,000	$426,000	$342,000	$289,000	$492,000	$1,496,000
HVAC System ($/$ft^2$)	$15.49	$14.68	$11.39	$11.03	$15.21	$8.92	$19.45
Heat Pumps ($)	n/a	n/a	n/a	n/a	n/a	$159,000	$303,000
Heat Pumps ($/$ft^2$)	n/a	n/a	n/a	n/a	n/a	$2.88	$3.94
Heat Pumps ($/ton)	n/a	n/a	n/a	n/a	n/a	$1,359	$1,390

Table 1: Specification and cost details for Illinois one-pipe loop ground source heat pumps.

How did this Concept Get Started
WSHP (Net Energy Loop) Schematic

Most common because it is lower cost, BUT…

Parallel Piping - Direct Return Piping



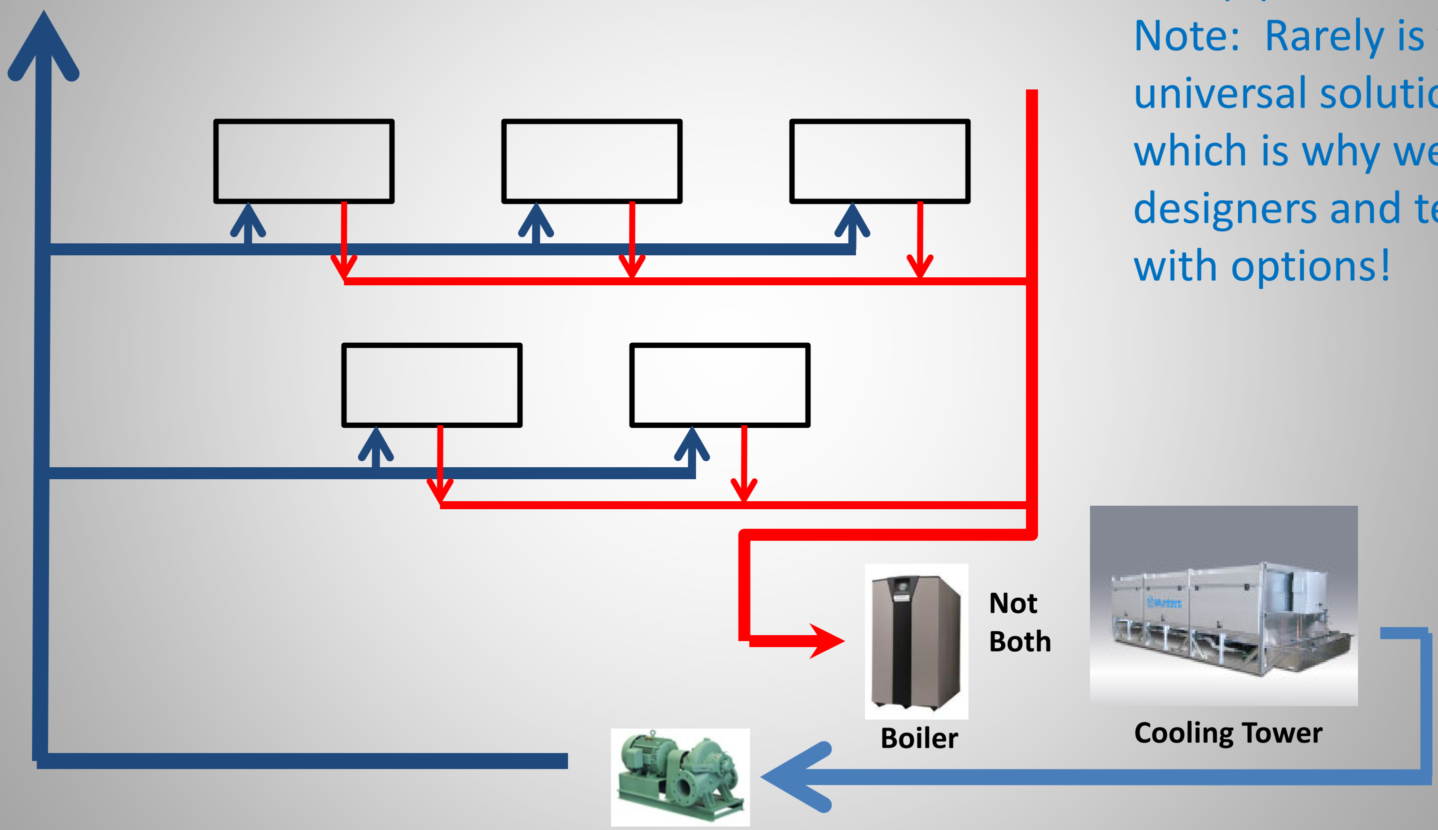
But… – what?
Balancing and commissioning

- Detail design; at least 2 x 4-Pipe
  - Transitions – stepped pipe
    - Must know Unitary GPM and pressure drop
- Control Valves – Pressure ratings and close off
- Flow Controls
  - Stop too much flow only
  - Cleanable - Strainers to protect them
  - Cost and pressure drop – Maintenance points
- Pump sizing – VFD’s and control logic

WSHP Basics – System Schematic

Intent was to be self-balancing

Parallel Piping - Reverse Return Piping

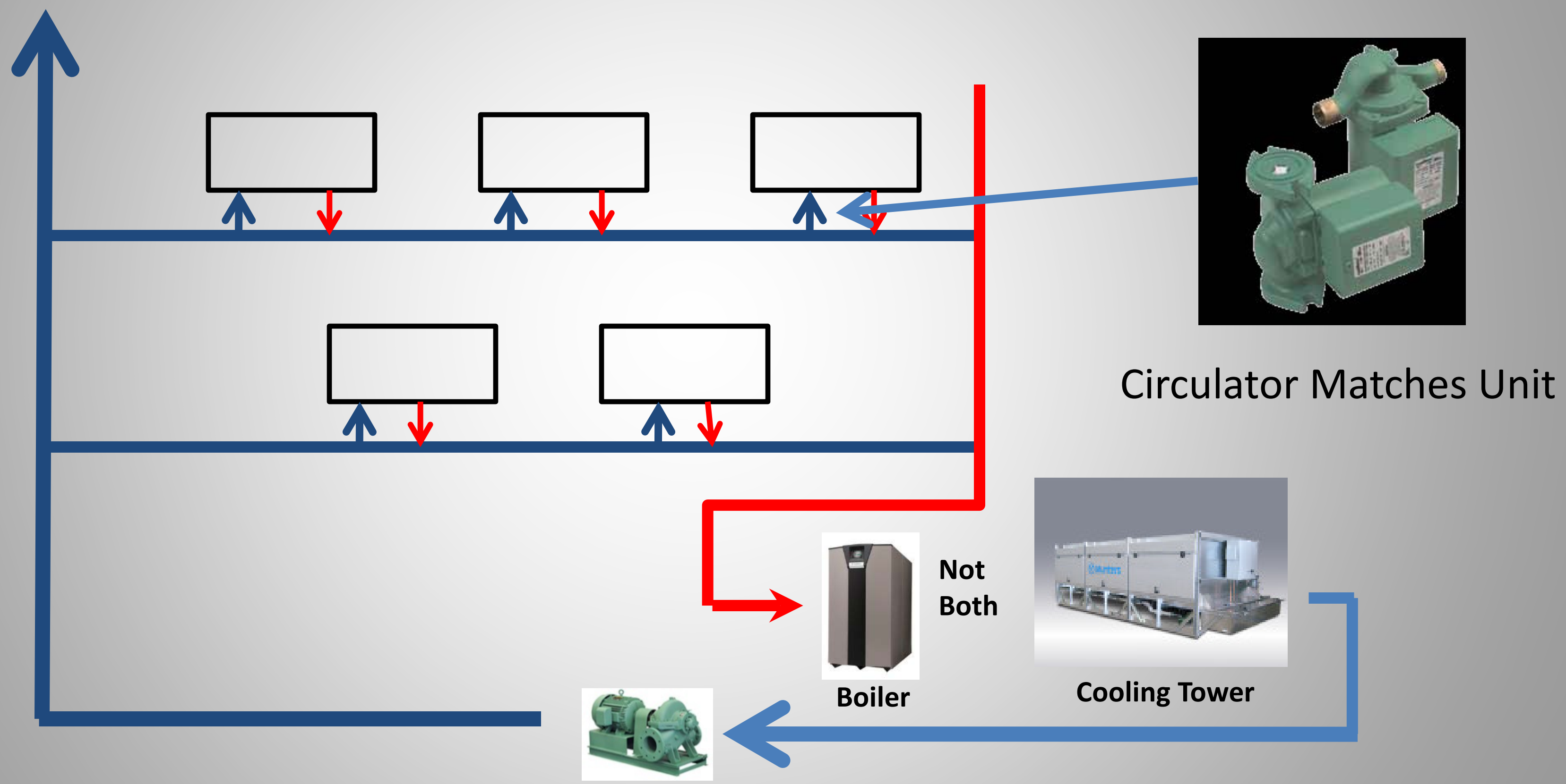


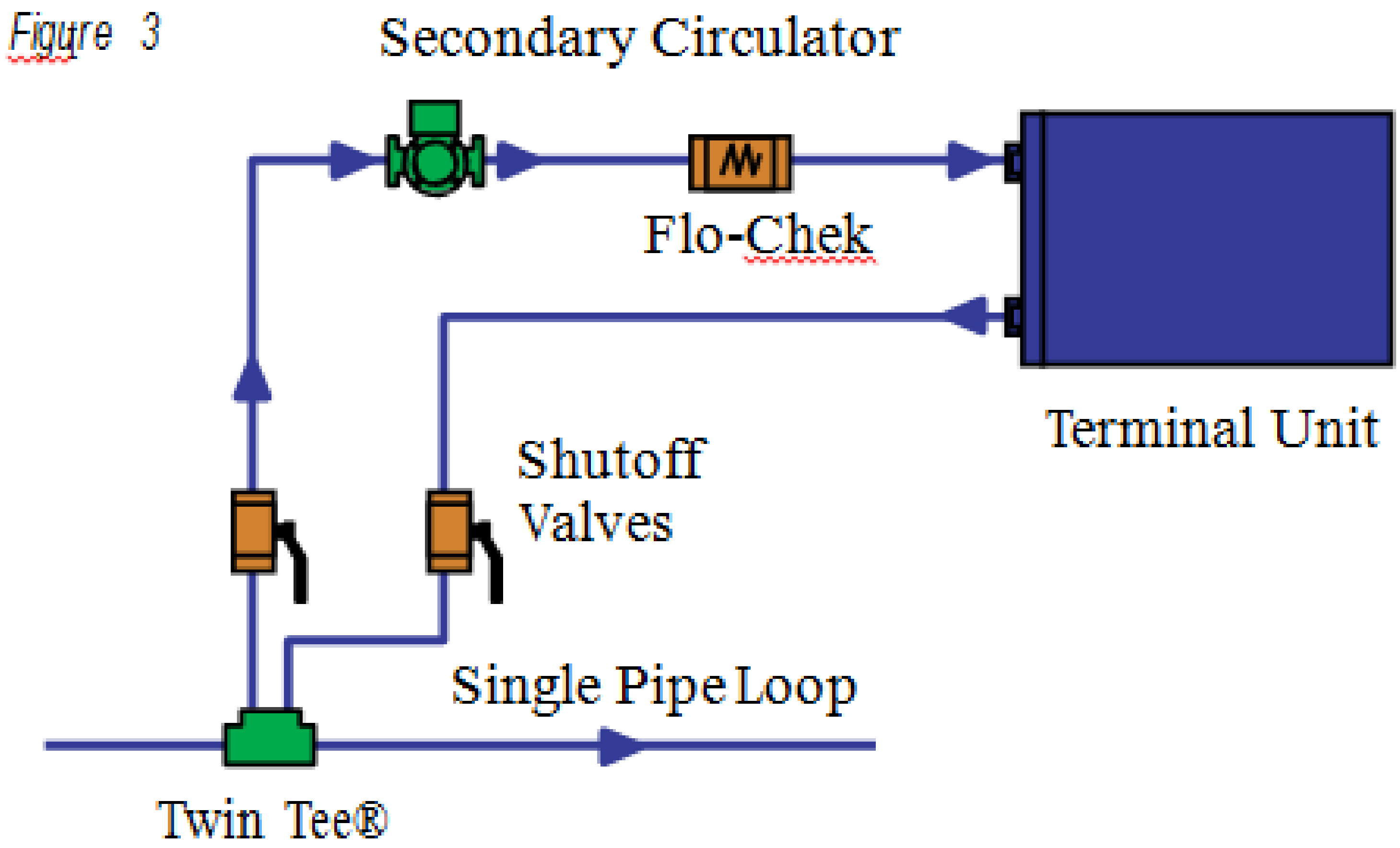
We will now discuss one-pipe distribution. Note: Rarely is there a universal solution, which is why we need designers and teams with options!

WSHP Basics – System Schematic

In the old days there was MONOFLOW heating

LoadMatch; One-pipe; 1x4-pipe - Reverse Return MAIN Piping

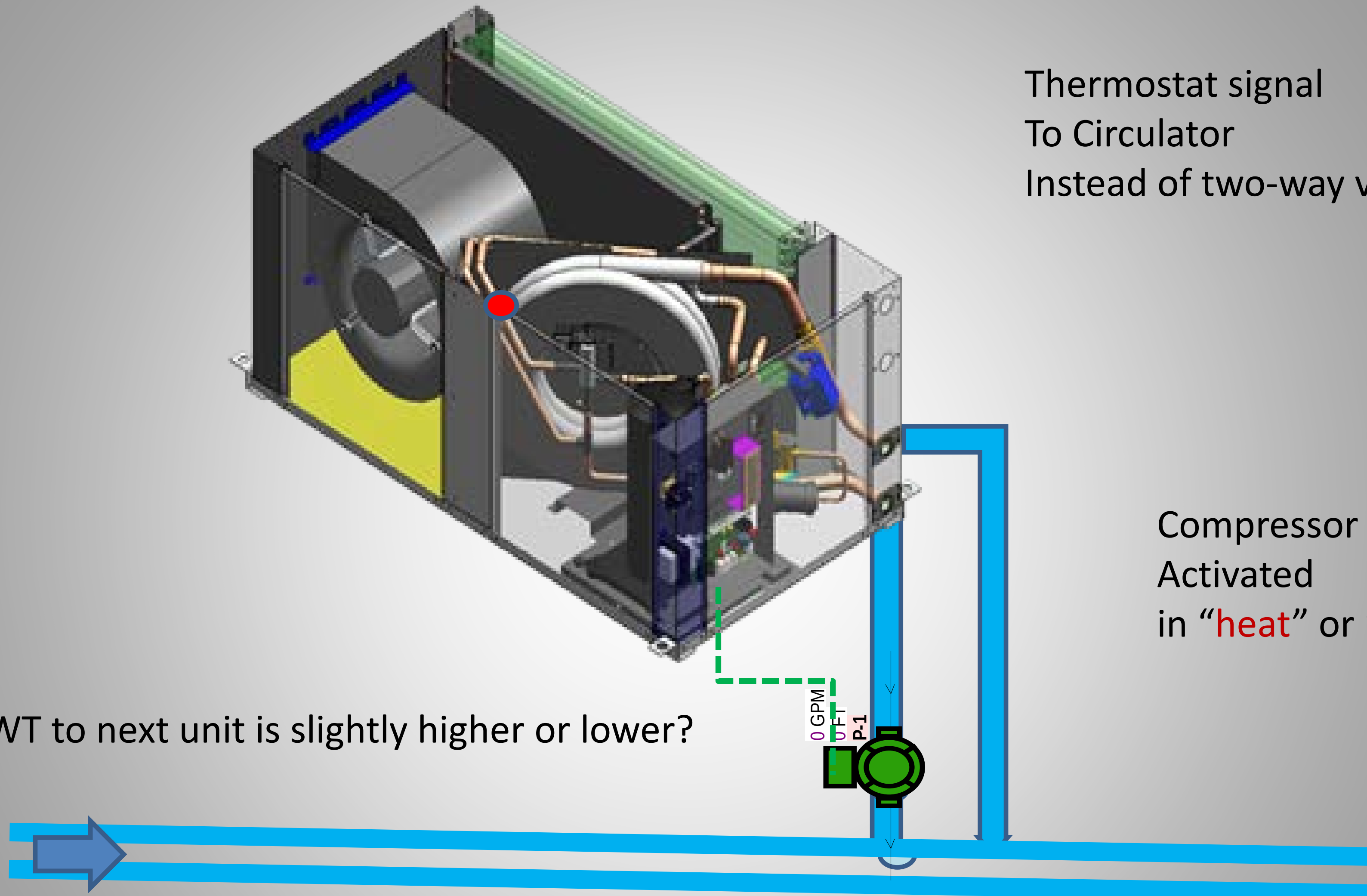




Since 1991 – Where has it been? Applied to coils not WSHP's

Moving Btu primary secondary pumping – One-pipe distribution (1x4-Pipe system)

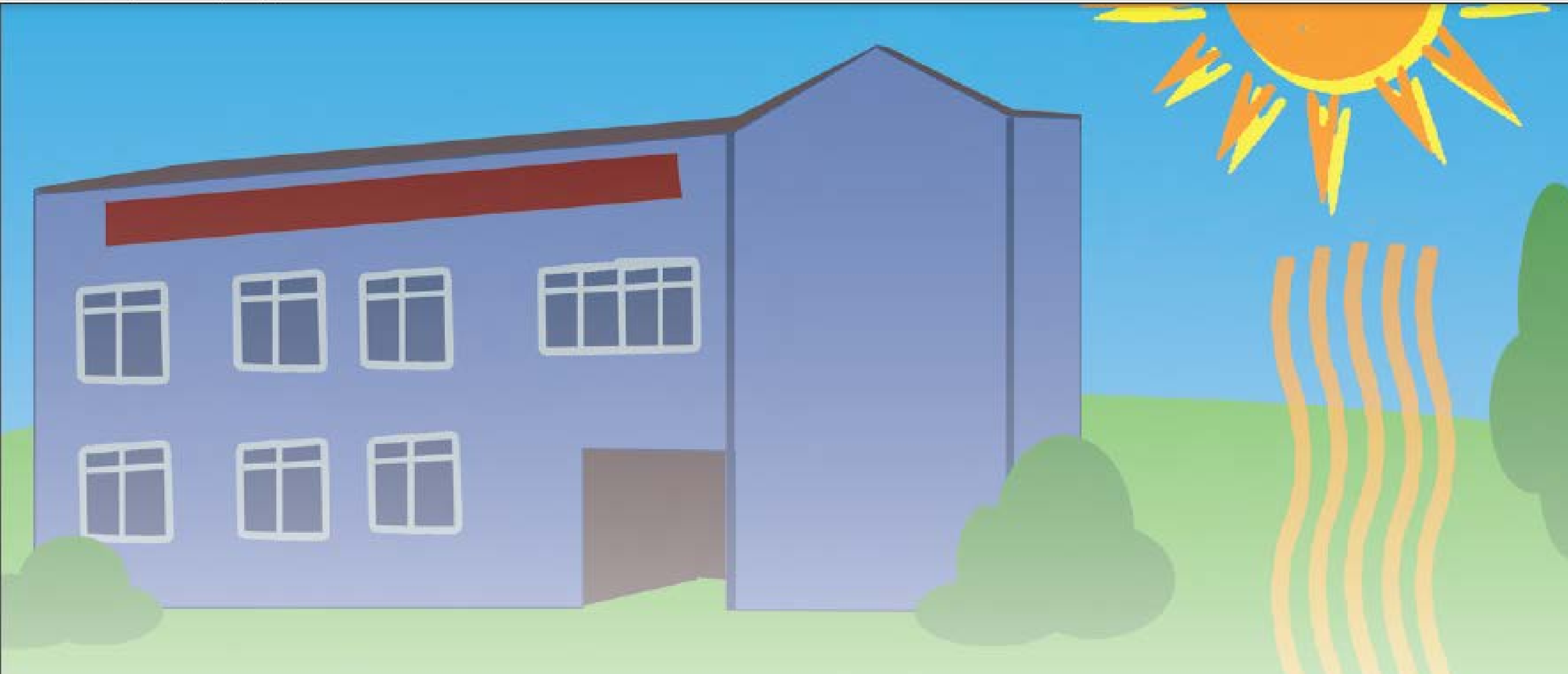
Thermostat signal
To Circulator
Instead of two-way valve



Compressor
Activated
in “heat” or “cool”

EWT to next unit is slightly higher or lower?

Flow in the main piping – typically - reverse return mains



One-Pipe Geothermal Design

Simplified GCHP System

By Kirk Mescher, P.E., Member ASHRAE

limited in size because, otherwise, the pressure drop of the overall system

ASHRAE Journal, October 2009

Why did we talk about this?

"Current benchmarks for distribution loop pumping power in vertical closed-loop systems (two-pipe design) call for a target of 7.5 hp per 100 tons (5.6 kW per 352 kW) of peak block cooling load.

Because the head loss through a one-pipe network is low, primary pumping requirements often are held to less than

***2 hp/100 tons** (1.5 kW/352 kW)."*

One-Pipe Advantages
Reduced First Cost

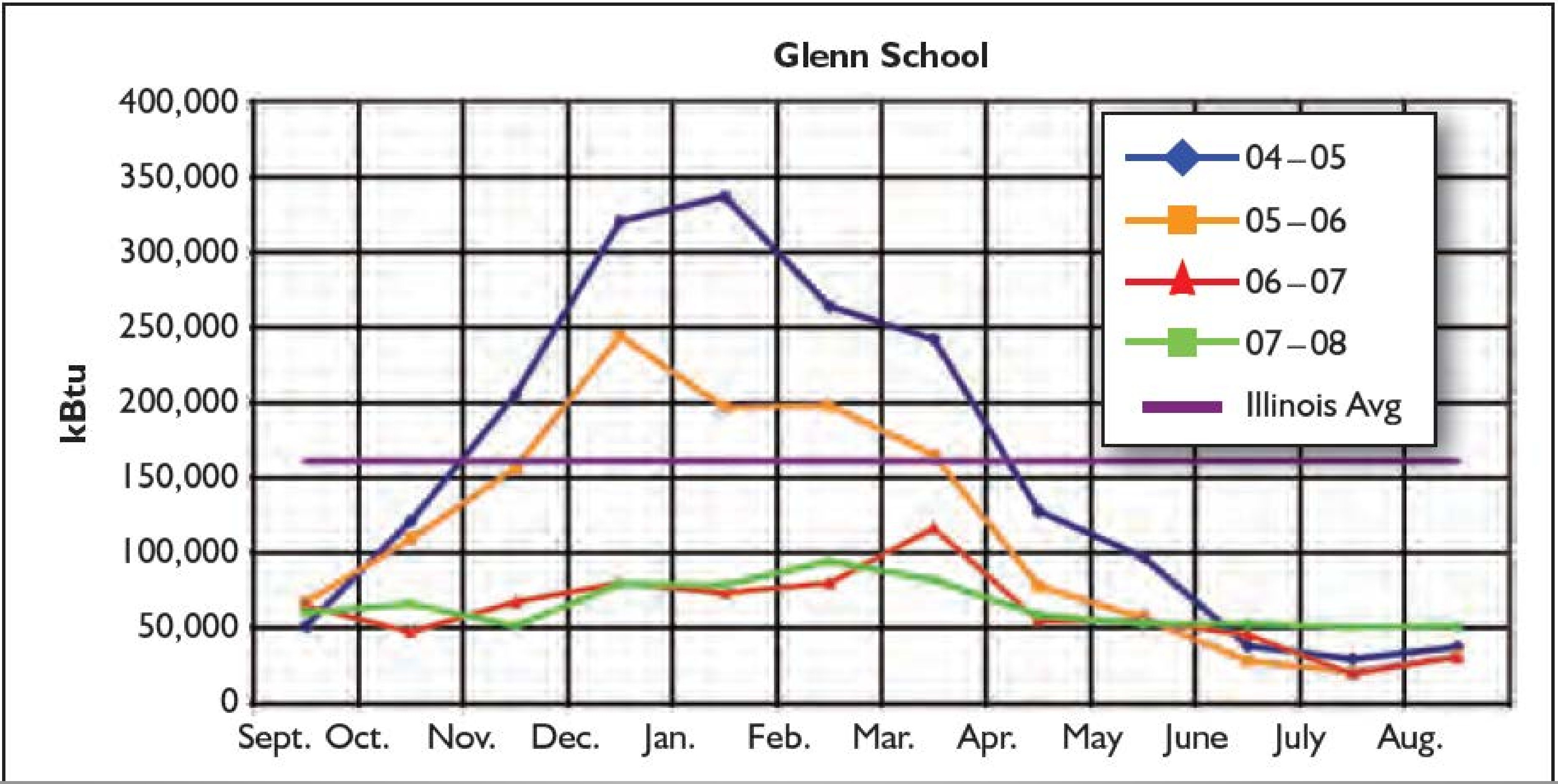
In a two-pipe network system, additional pipe and pipe fittings are required over the one-pipe arrangement.

Multiple one-pipe installations in schools and office buildings have shown a piping installation ***cost savings of $0.50 to $1.50/ft2*** *($5.38 to $16.15/m2).*

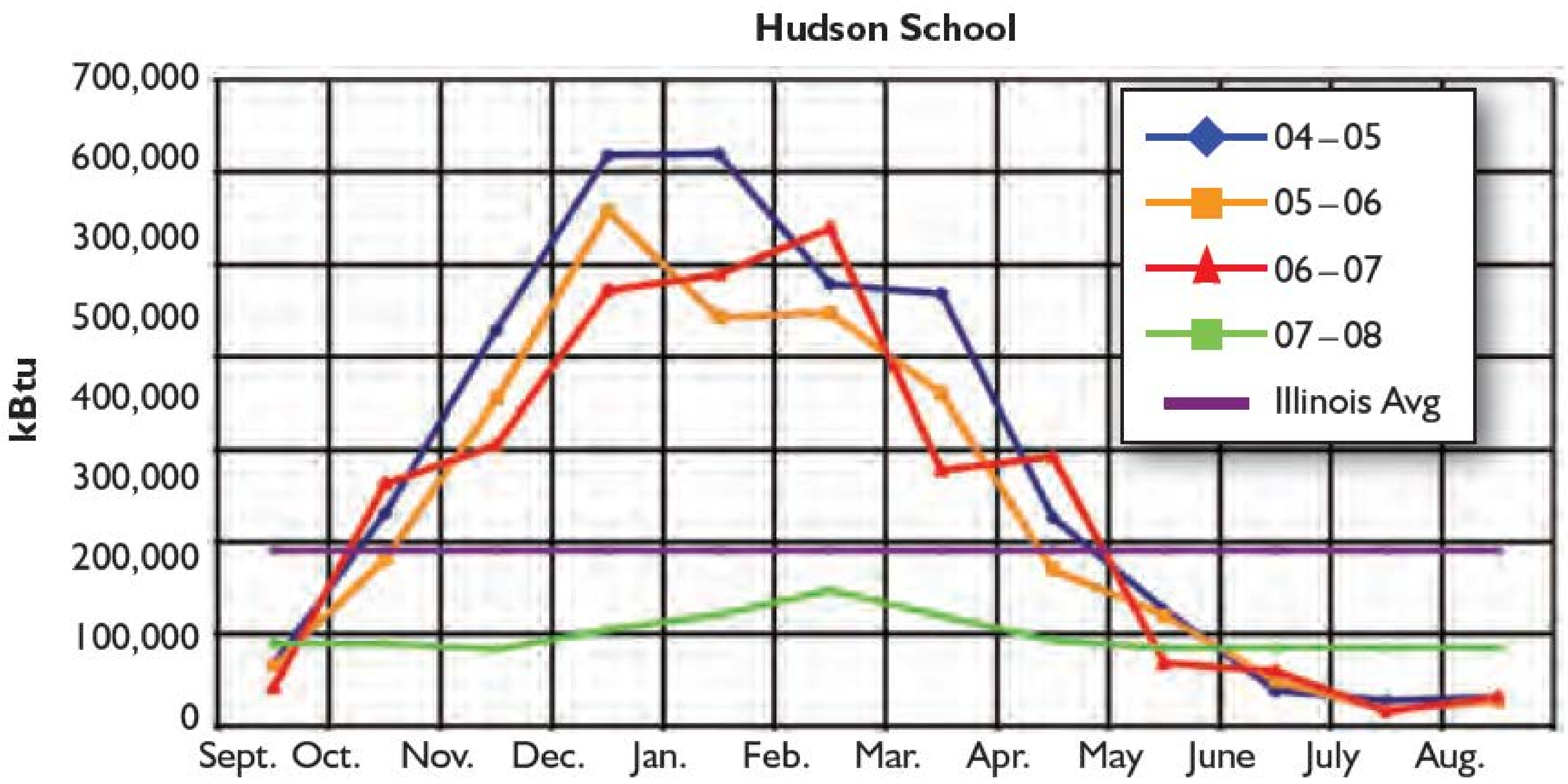
These (following 4 slides) systems are in the range of 50 to 200 tons (176 to 703 kW) and are located in Illinois.

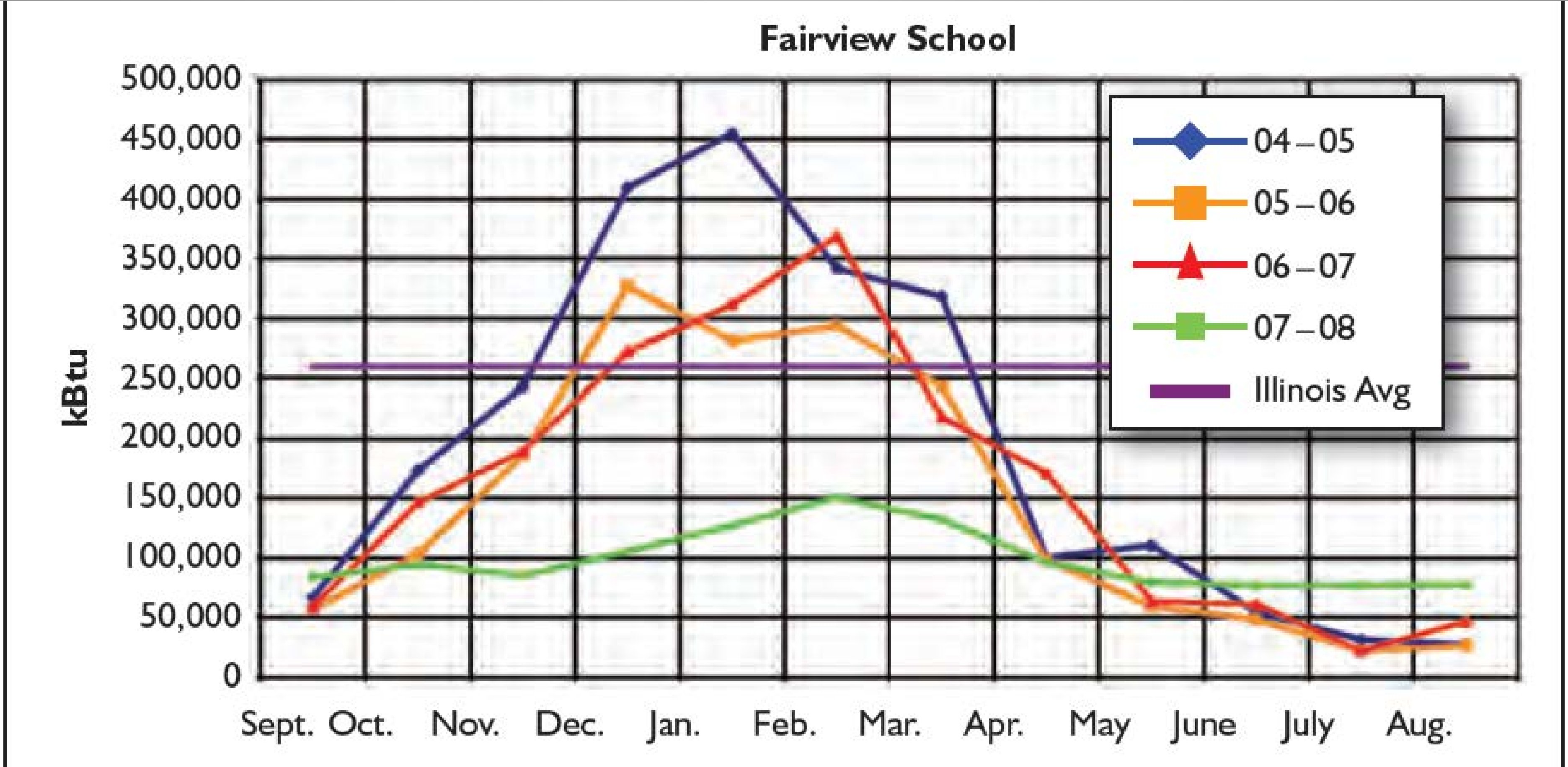
Monthly Energy profile – kBtu

Illinois Average for schools
2005 – NO central air conditioning
2006 – energy measures in operation
2007 and 2008 – one-pipe Geothermal



One year data for One-pipe Geothermal

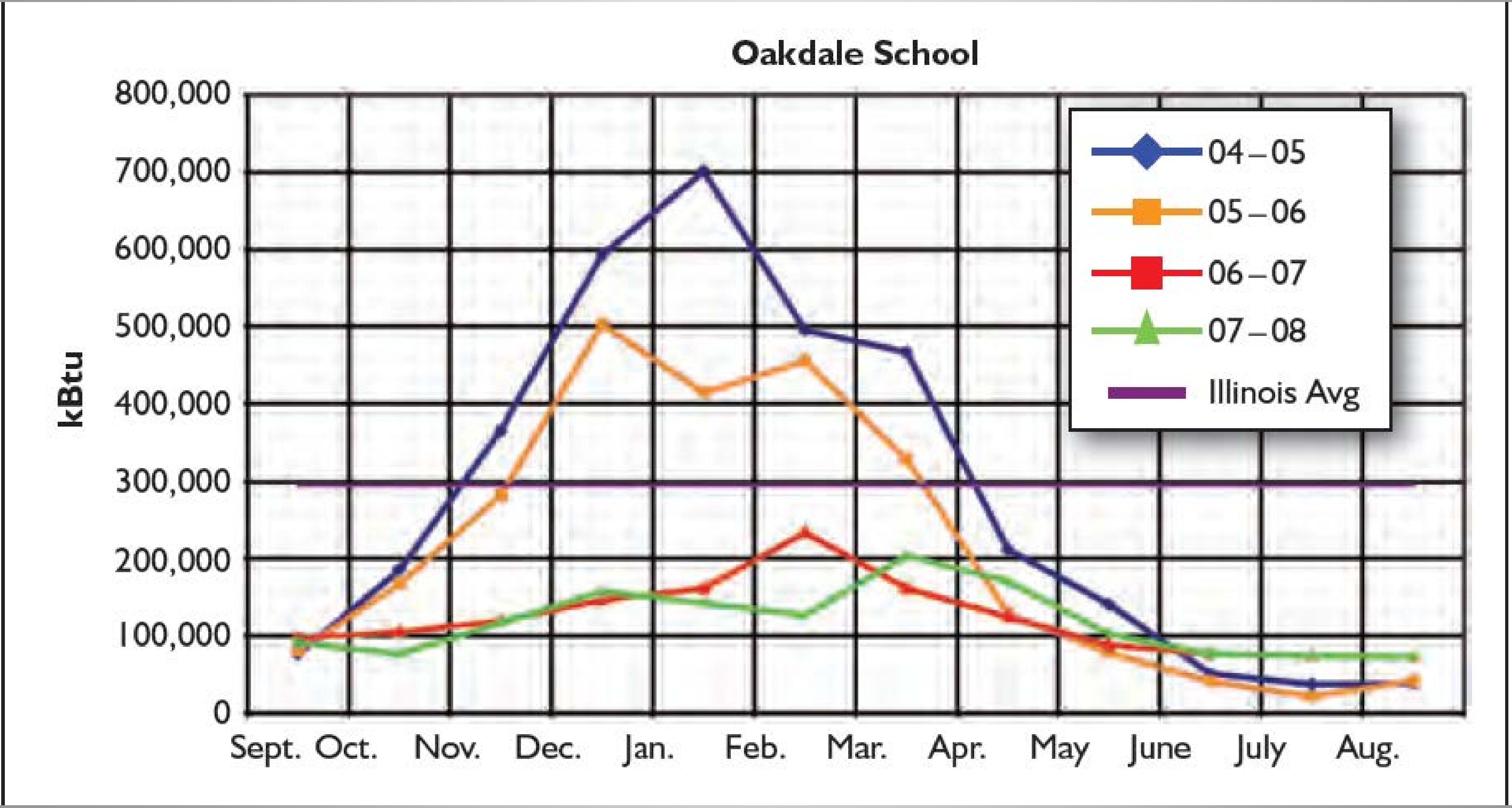




Different School another one year comparison

Fourth School – Two years of One-pipe

First two years – Old Boiler – No Air Conditioning

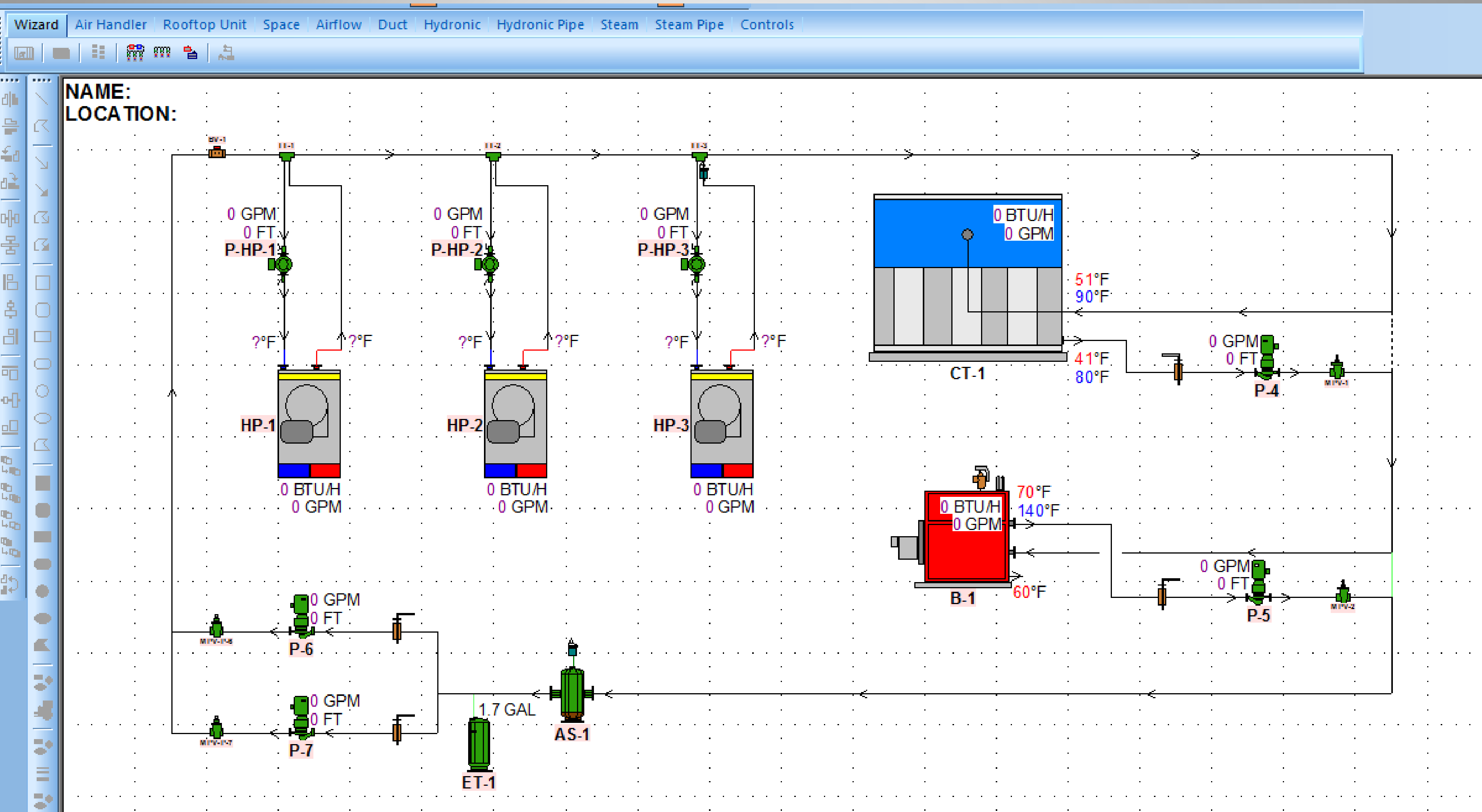


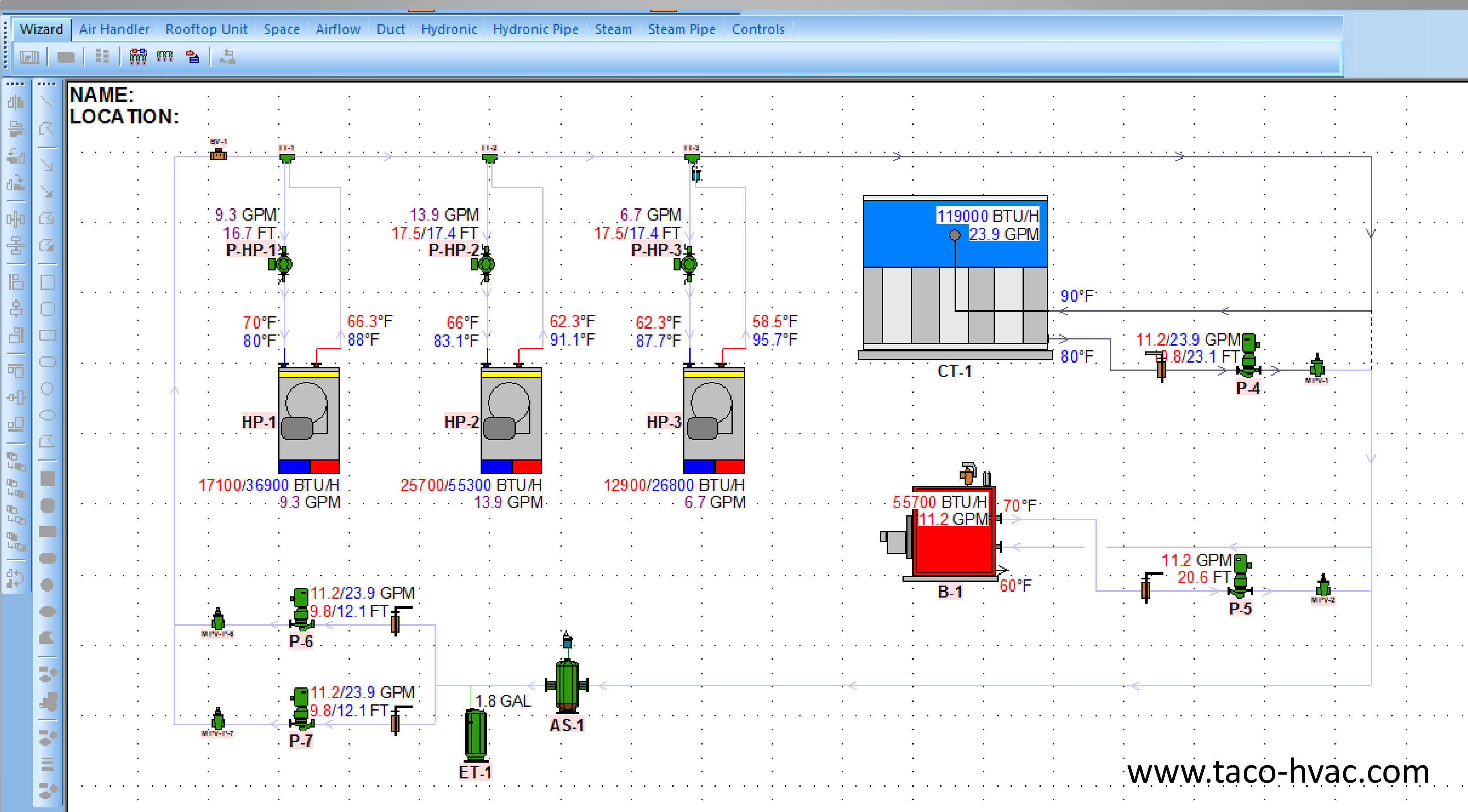
“Field-Measured Results
These systems have produced exceptional maintenance and operational histories.

Without physical modification to the buildings, one-pipe GCHP systems have placed buildings in the top 10% of all schools in the ENERGY STAR performance measurement program, designated within the climate zone for Illinois.”

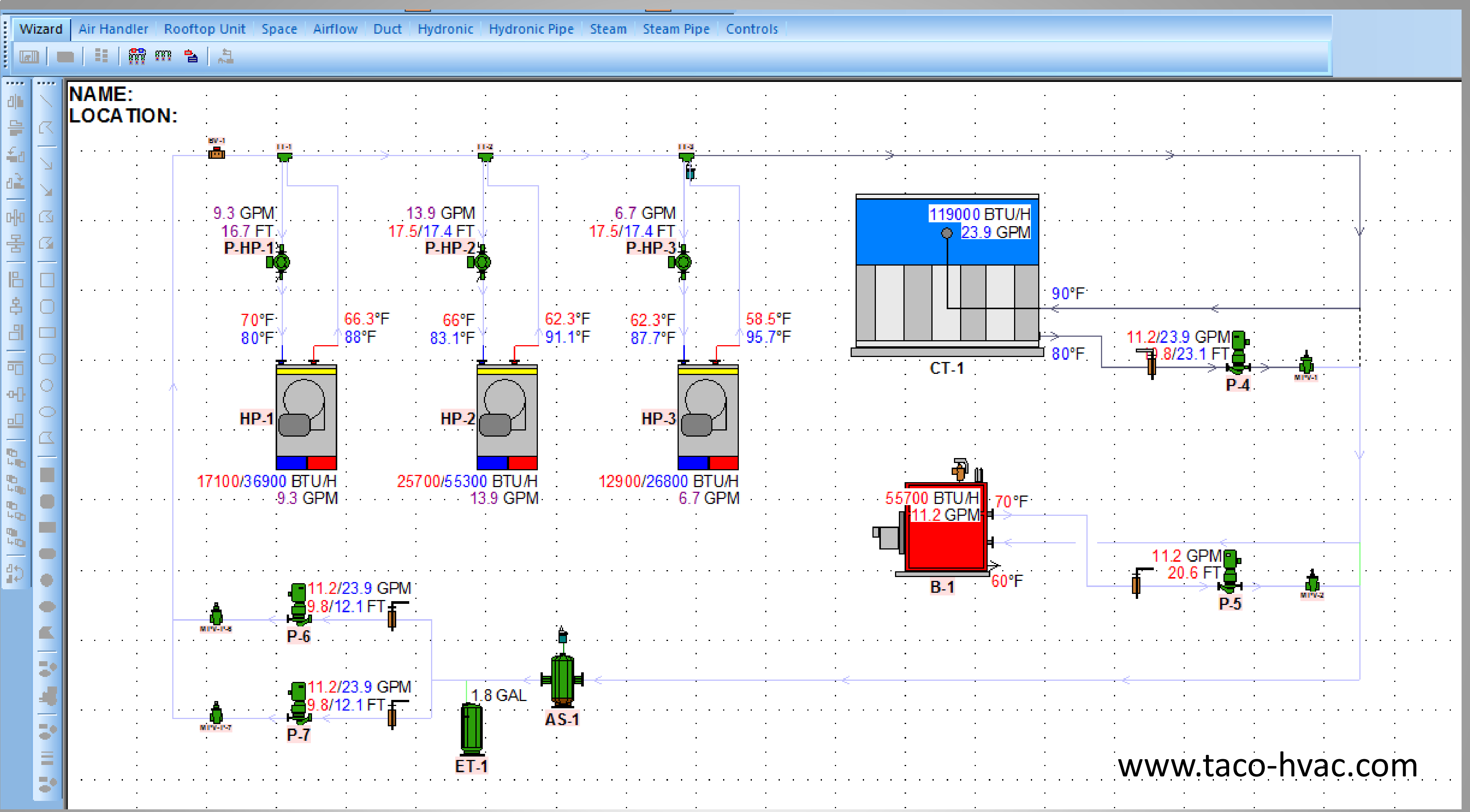
Simple Boiler Tower

The pipe is sized for the load at a velocity and a design maximum Delta-T





This wizard shows operation at a 10 degree delta-T
BUT it may never Happen!



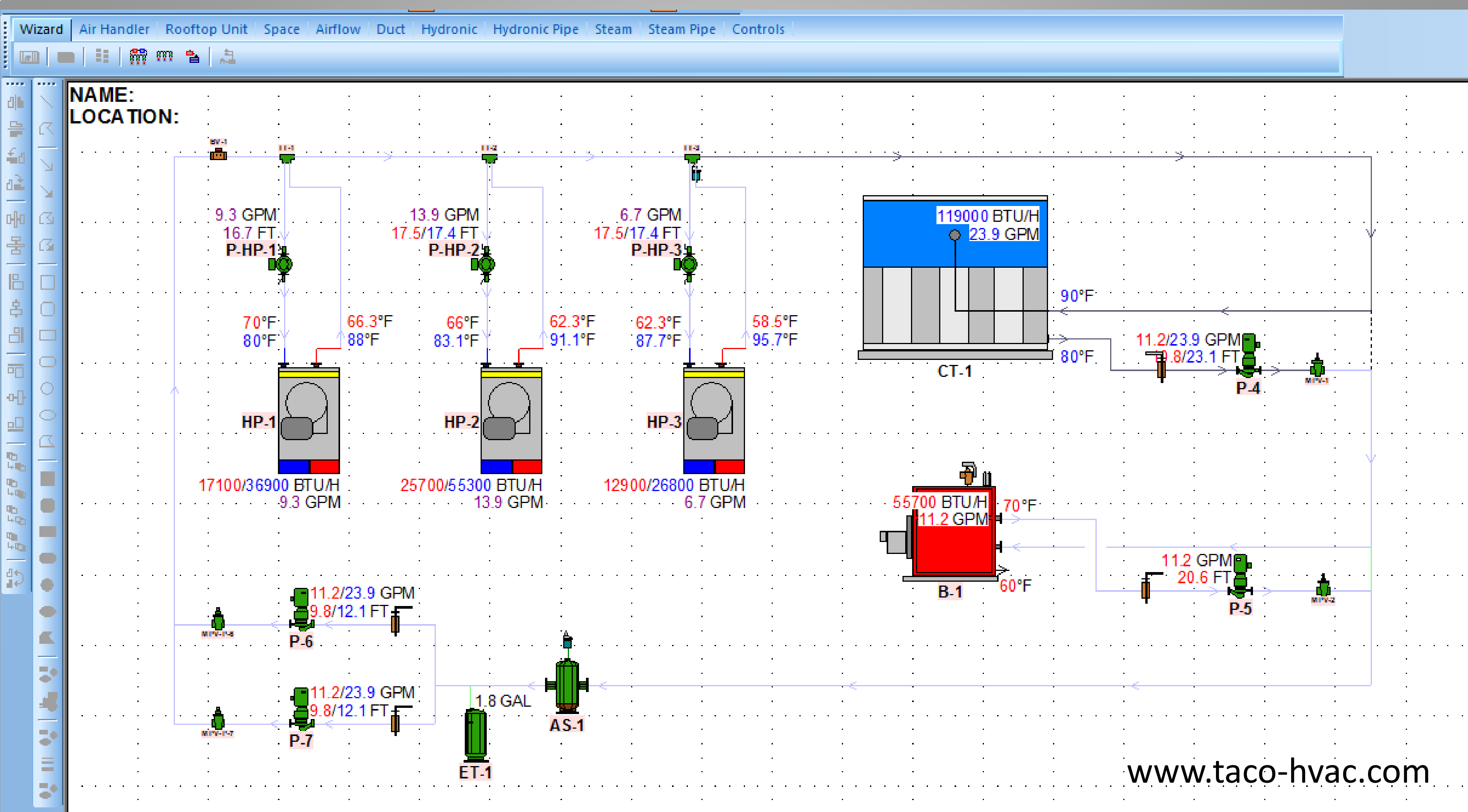
www.taco-hvac.com

One unit is "OFF" – the middle one

Therefore third unit entering conditions are what the second shows above

Remember

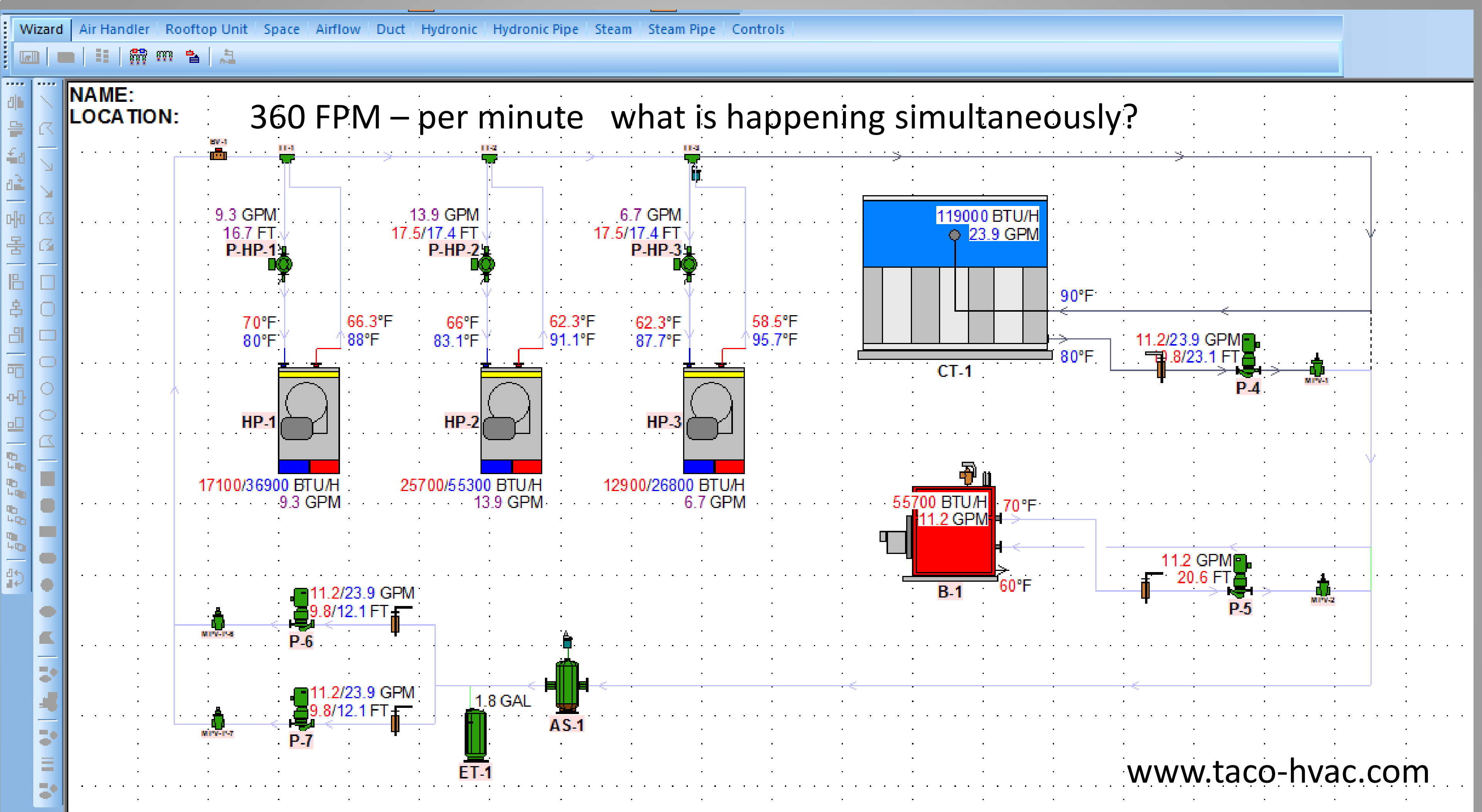
WSHP systems do not have low Delta-t syndrome!



One unit Heating and two units are Cooling = Net Energy Loop

Remember

WSHP systems do not have low Delta-t syndrome!



Why Design Delta-T does not CASCADE with WSHP

Units do not operate at design day conditions

Run fraction – "off" vs. "on" plus Heat vs. Cool

Demand Controlled Diversity

Why is the WSHP Energy Profile positive?
Demand Controlled Diversity to Net Energy

System Energy Consumption is moving Btu to provide the Comfort Condition

Based on **Owner Requirements** for zones of control

Designer innovation and analysis of the energy template

Pump horsepower is demand controlled with circulators that ensure flow

Btu's move in water at 10% of cost to move in Air

Compressor horsepower is demand controlled and water–cooled

The Net Energy loop avoids Peaks – high or low vs. Outside Air

Blower horsepower is demand controlled and ducted as required.

ECM blowers allow units flexibility and improved performance

The Design is to Net Energy, use it or lose it!

The first step to Net Zero is reduce the loads
The second step is to net the loads against each other
The third step is do it efficiently based on Owners Budget

Can it really be this simple?

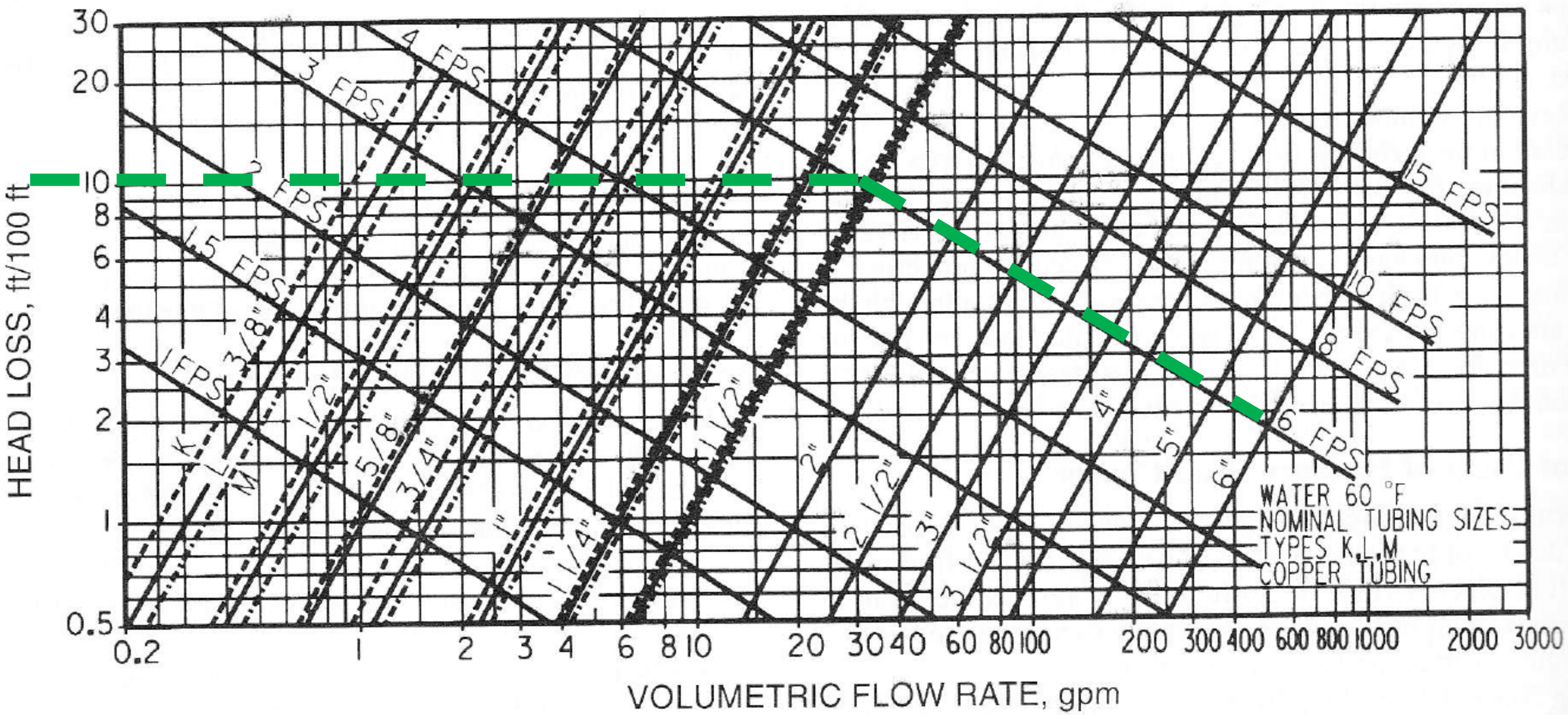


Fig. 2 Friction Loss for Water in Copper Tubing (Types K, L, M)

Pipe is sized like a coil – Start with Maximum flow per your requirements
Do it ahead based on your limits.
I chose: Max head loss of 10 feet/100 ft.
And 6 FPS velocity

Can it really be this simple?

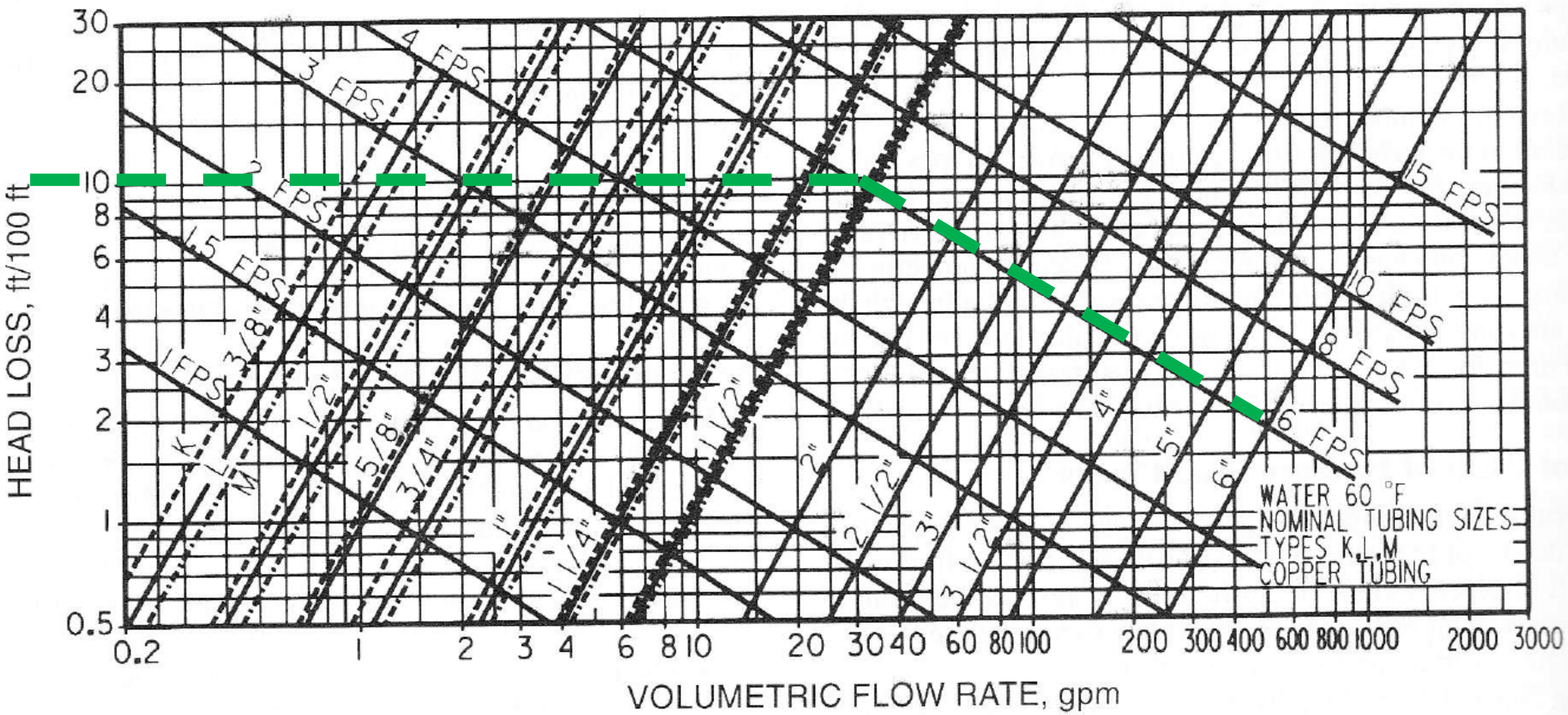


Fig. 2 Friction Loss for Water in Copper Tubing (Types K, L, M)

So from the chart above:

1" Pipe = 12.5 GPM, it is your rules so you can adjust

1 ¼" = 22.5 GPM

1 ½" = 33.0 GPM

2" = 60 GPM; 2 ½" = 90 GPM; 3" = 130; 4" = 250, etc.

Can it really be this simple?

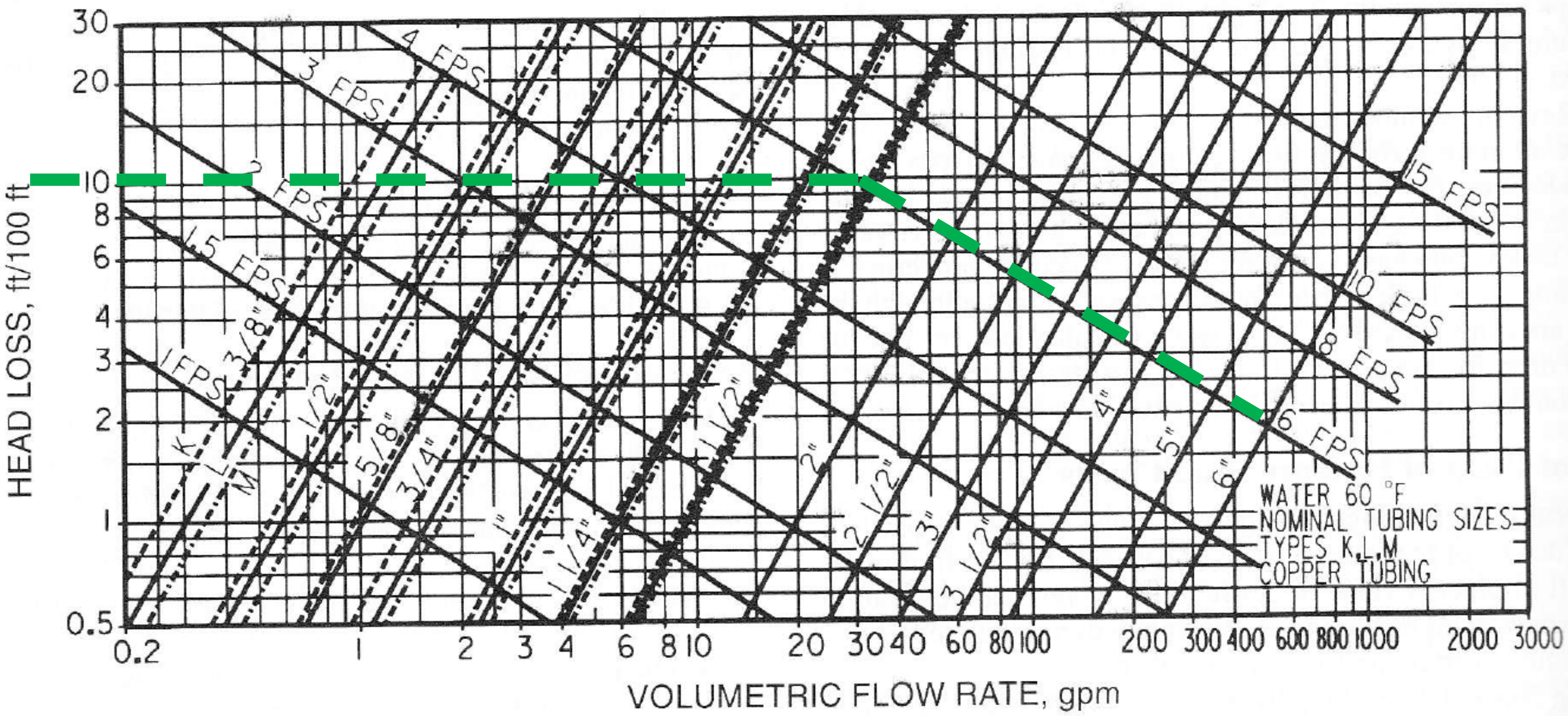


Fig. 2 Friction Loss for Water in Copper Tubing (Types K, L, M)

So from the chart above:

1" Pipe = 12.5 GPM, or divided by 2 GPM/ton (12°F Delta-T) = 6.25 tons

1 ¼" = 22.5 GPM = 11.25 tons

1 ½" = 33.0 GPM = 16.5 tons of load served by a 1 ½" pipe

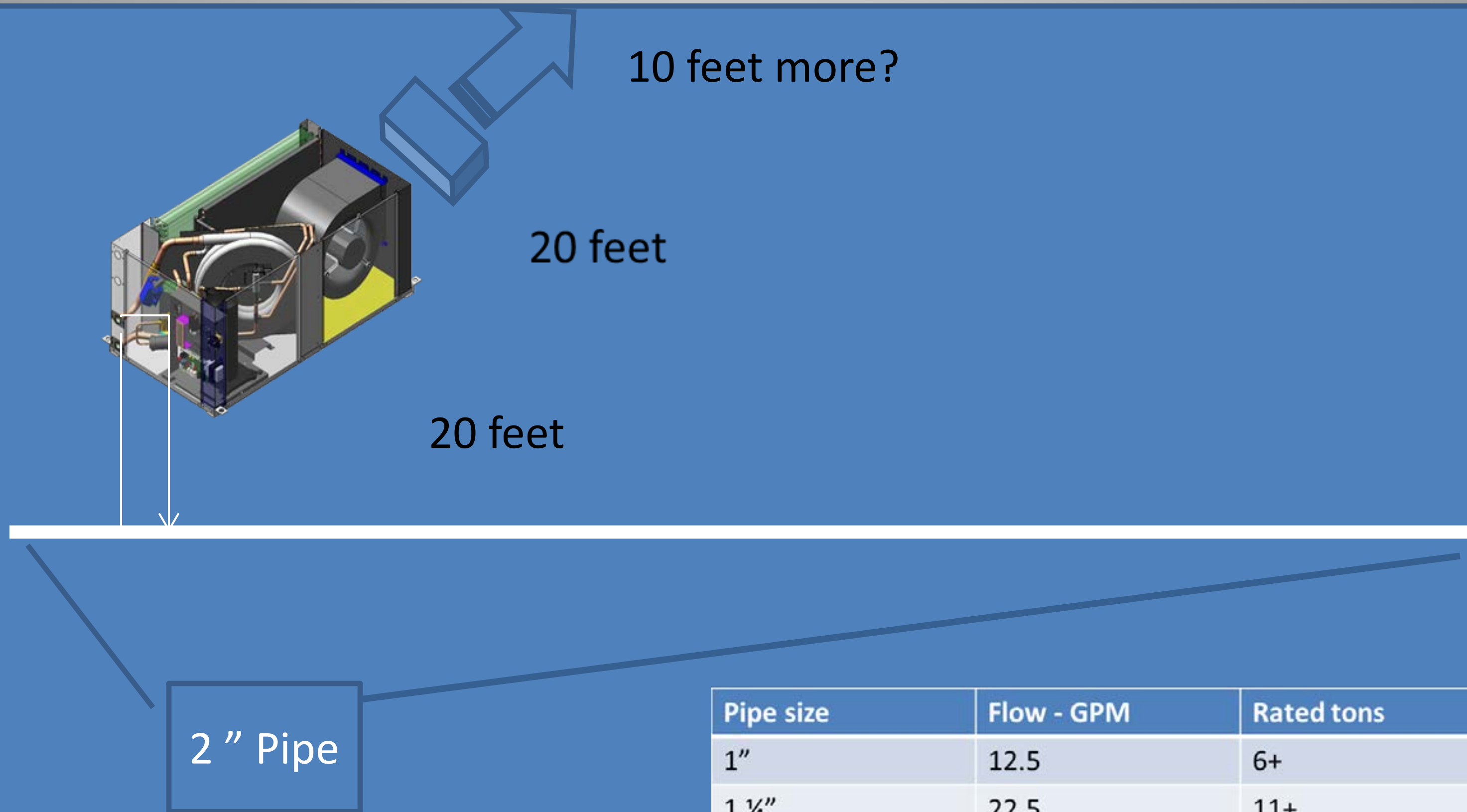
2" = 60 GPM; 2 ½" = 90 GPM; 3" = 130; 4" = 250, etc.

A Simple chart – allows you to layout a piping schematic

Pipe size	Flow - GPM	Rated tons
1”	12.5	6+
1 ¼”	22.5	11+
1 ½”	33	16+
2”	60	30
2 ½”	90	45
3”	130	65 maybe +

Select the most economical pipe size
Mains are reverse return

Floor plan – Customer does not know zoning – what do you do?

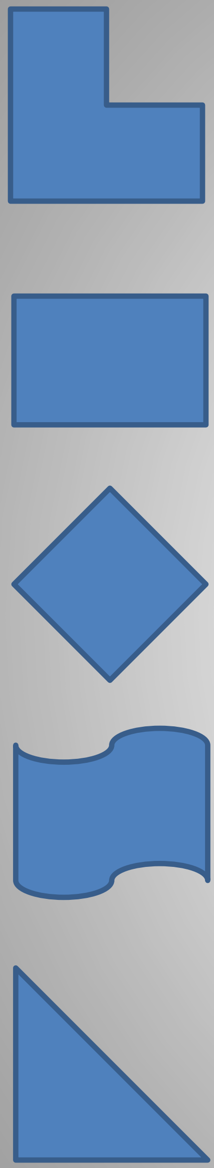


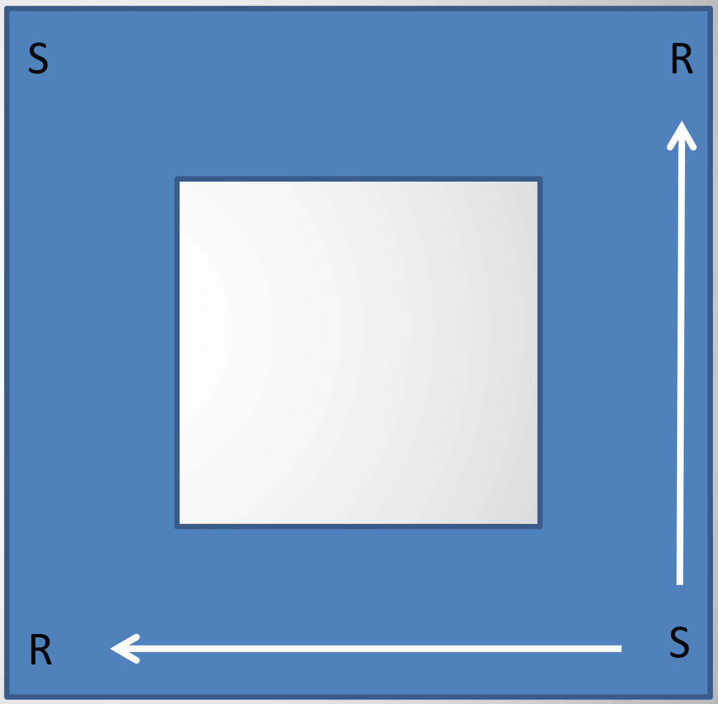
Pipe size	Flow - GPM	Rated tons
1”	12.5	6+
1 ¼”	22.5	11+
1 ½”	33	16+
2”	60	30
2 ½”	90	45
3”	130	65 maybe +

Floor plan – Simple answer could be - based on square footage and use = 30 tons

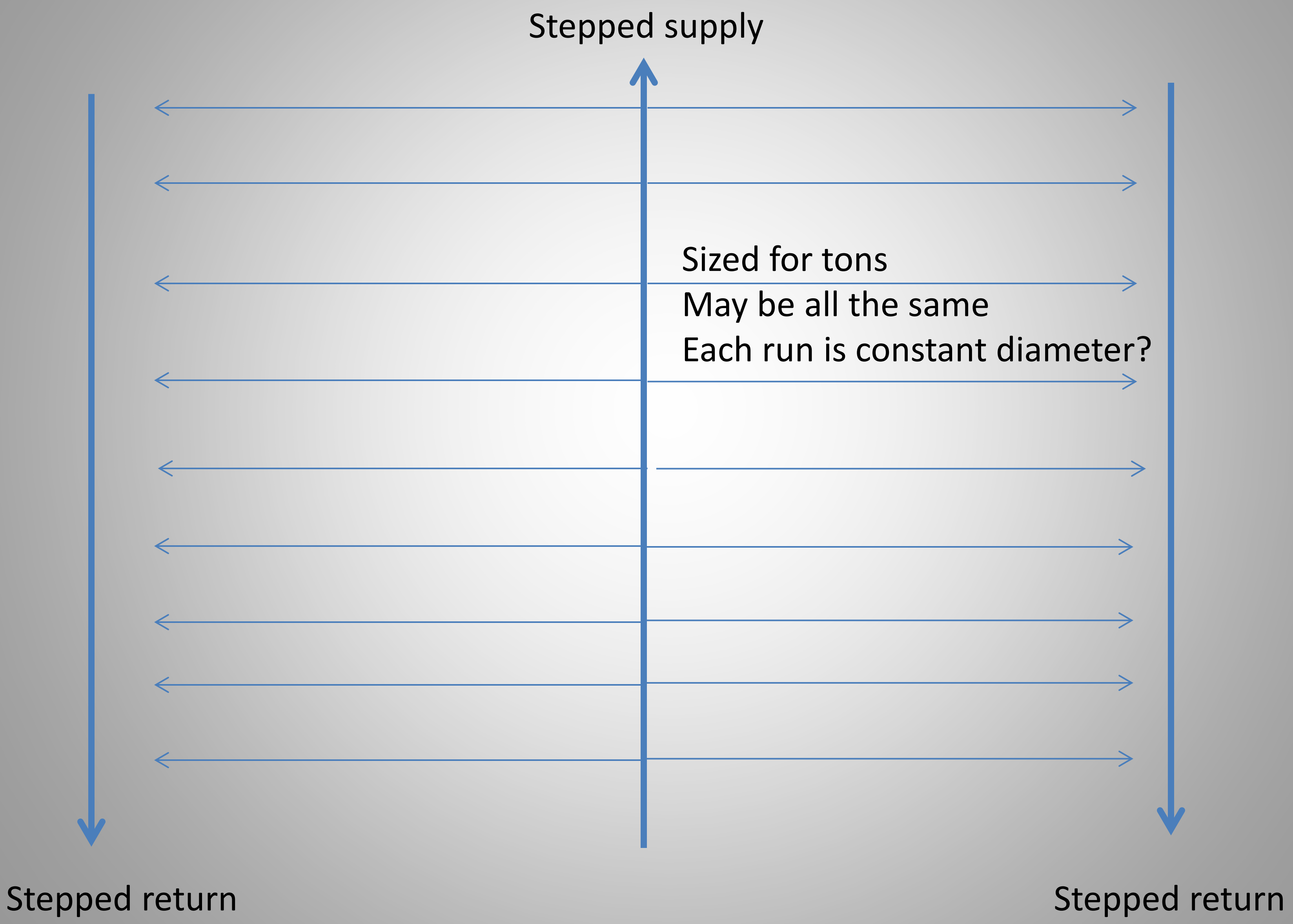
The shape really is the challenge

1. economical pipe size
2. location location location





I actually saw this done on a napkin!



1x4-pipe; It's an option

- Save labor and components
- Communicate Design to the field
- Demand Control
  - Unit compressor and blower HP
  - Now pump Horsepower
- Remove 50% of BHP requirement (head and $)
- Self-Balancing and Commissioning
- Flexible for budget and future

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