

# Experiences from Geothermal Heat Pump Systems with Variable Flow Pumping

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# Overview

- Look at various variable flow pumping systems
  - Lake-Front Hotel in Geneva, NY
  - McDonalds in suburban Detroit, MI
  - Daniel Boone High School in Johnson City, TN
  - Office Building in Williamsport, PA
- Issues affecting system success & performance
- Summary

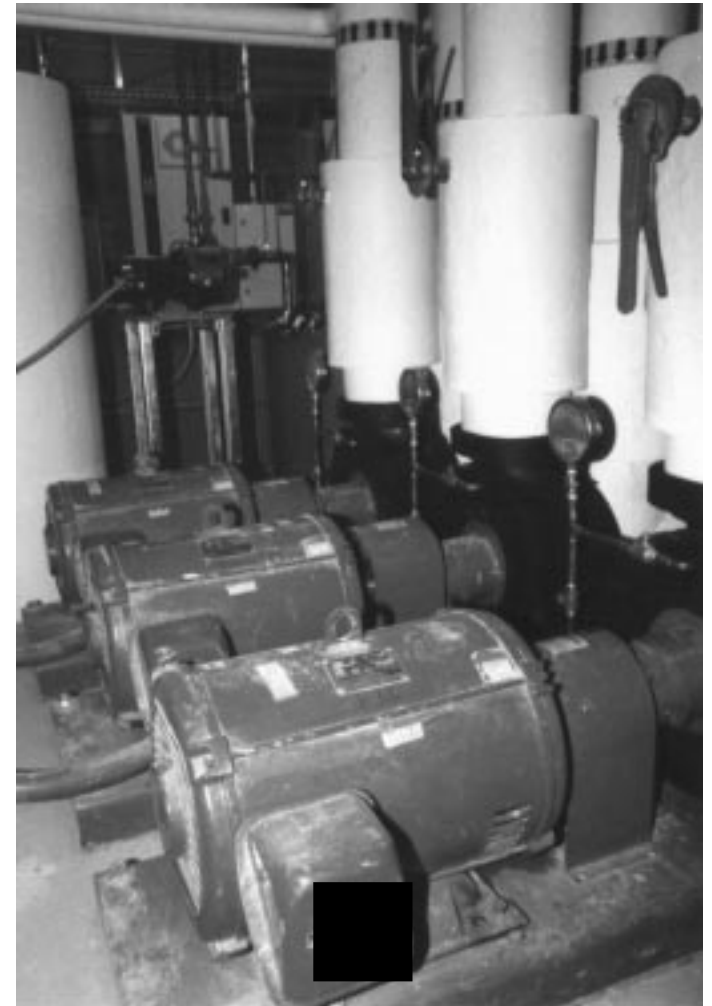
# Lake-Front Hotel - Geneva, NY

- 149 room Hotel  
100,000 ft<sup>2</sup>  
324 tons
- Geothermal HP System
  - space conditioning HPs
  - water heating HPs
  - variable speed loop pumping / Fresh air heat recovery
  - ground loop split between pilings and bore field saved \$100,000 on drilling

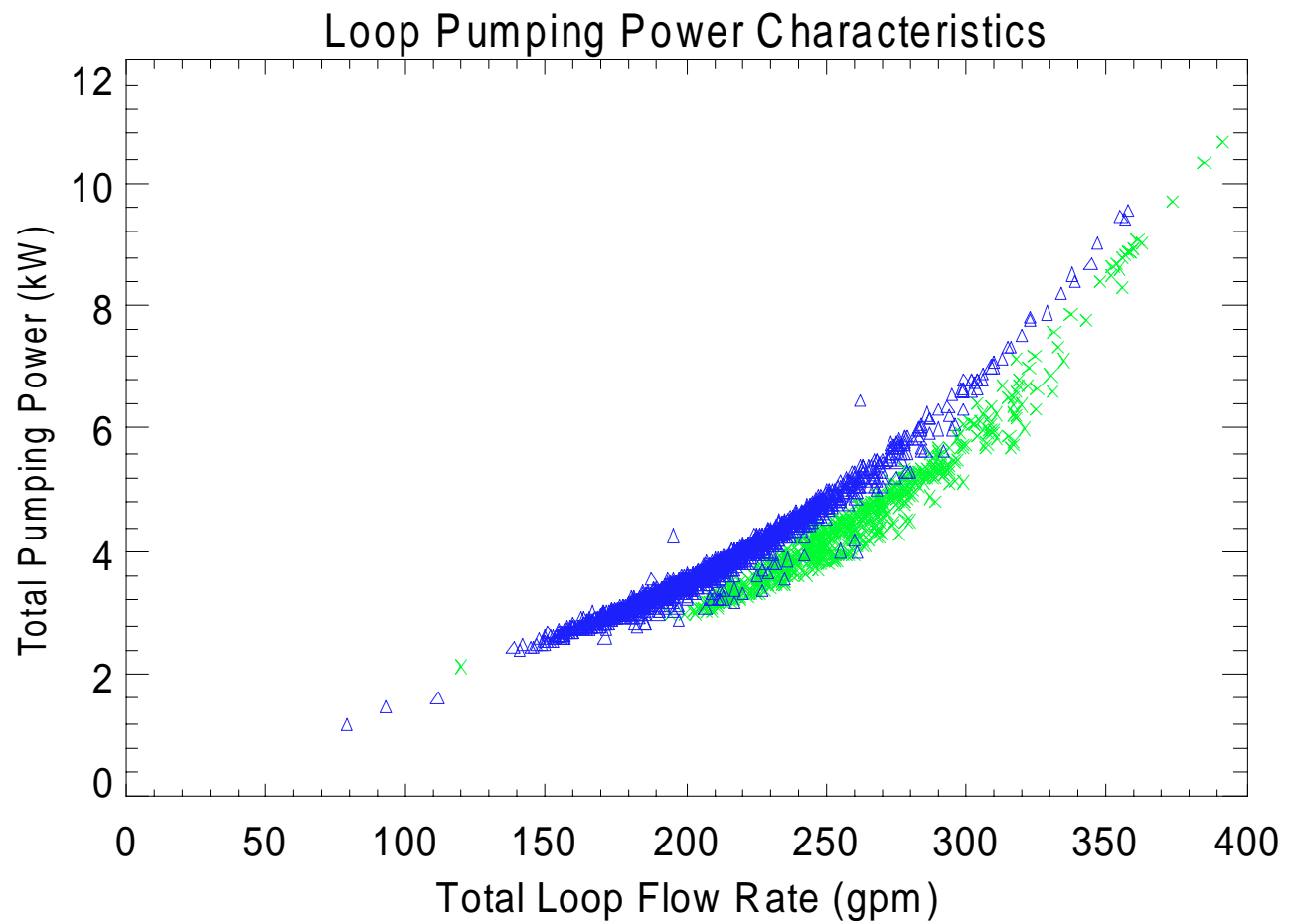


# Hotel - Loop Pumping

- Pumping system uses (3) 50 Hp pumps (one backup), 0.31 Hp/ton<sub>nominal</sub>
- Original “design” called for 30 Hp pumps , 0.19 Hp/ton<sub>nominal</sub>

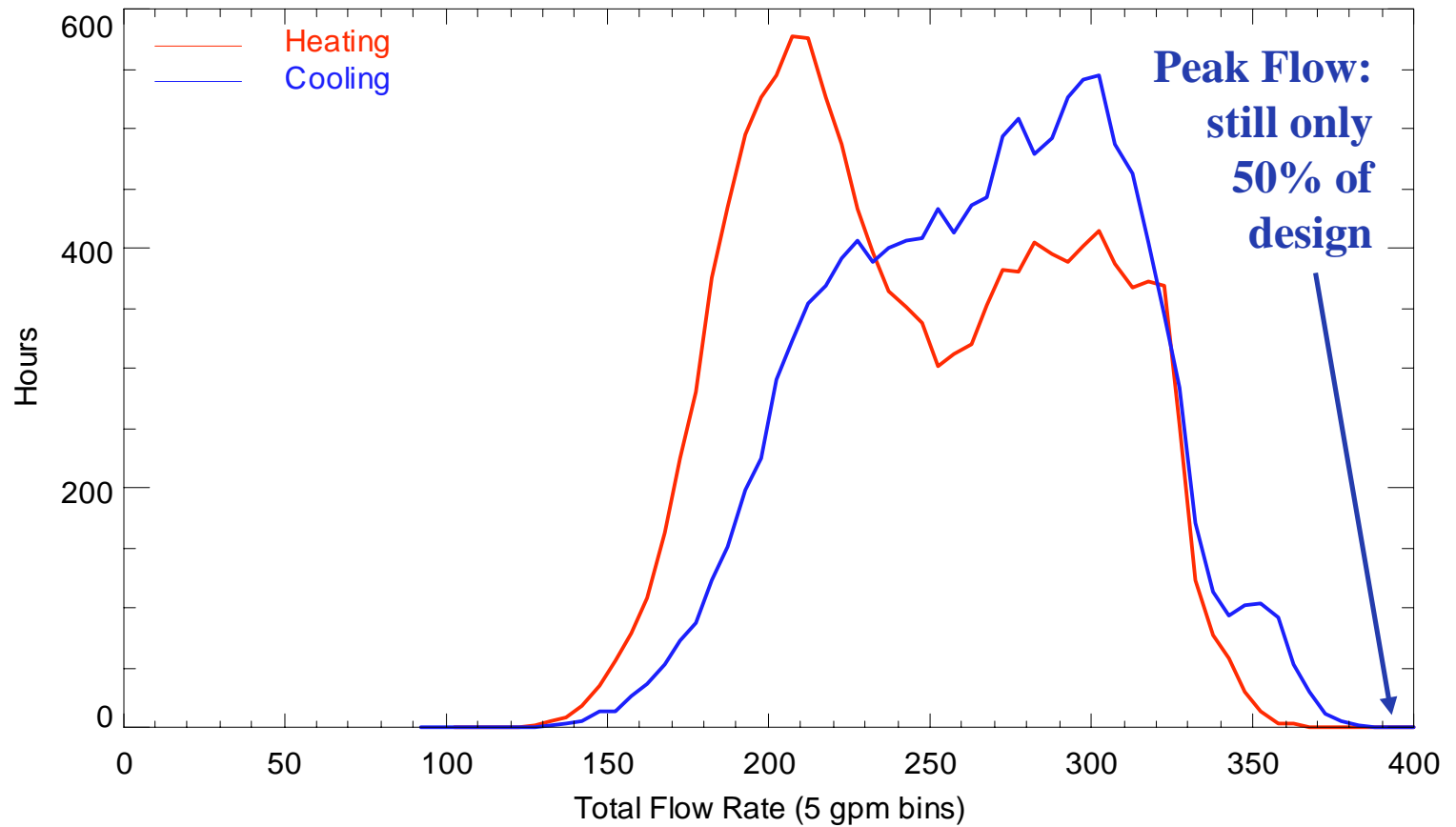


# Hotel - Minimum Turn-Down



15% Minimum turn-down

# Hotel - Annual Flow Distribution



# Hotel - Summary

- Loop pumps drastically oversized,
  - yet system able to “turn-down” to 15% of full flow
  - power use as low as 2 kW, or 6% of installed full-load power
- Annual pumping energy is only 11% of all HVAC
- Energy savings of 92% compared to two 30 HP pumps at constant speed

# McDonalds - Detroit, MI

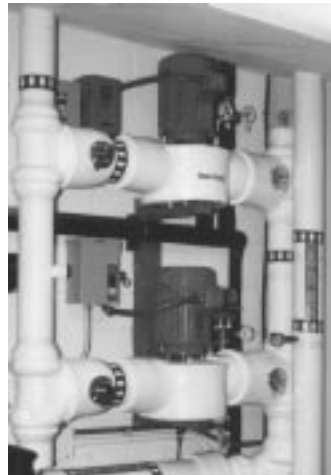
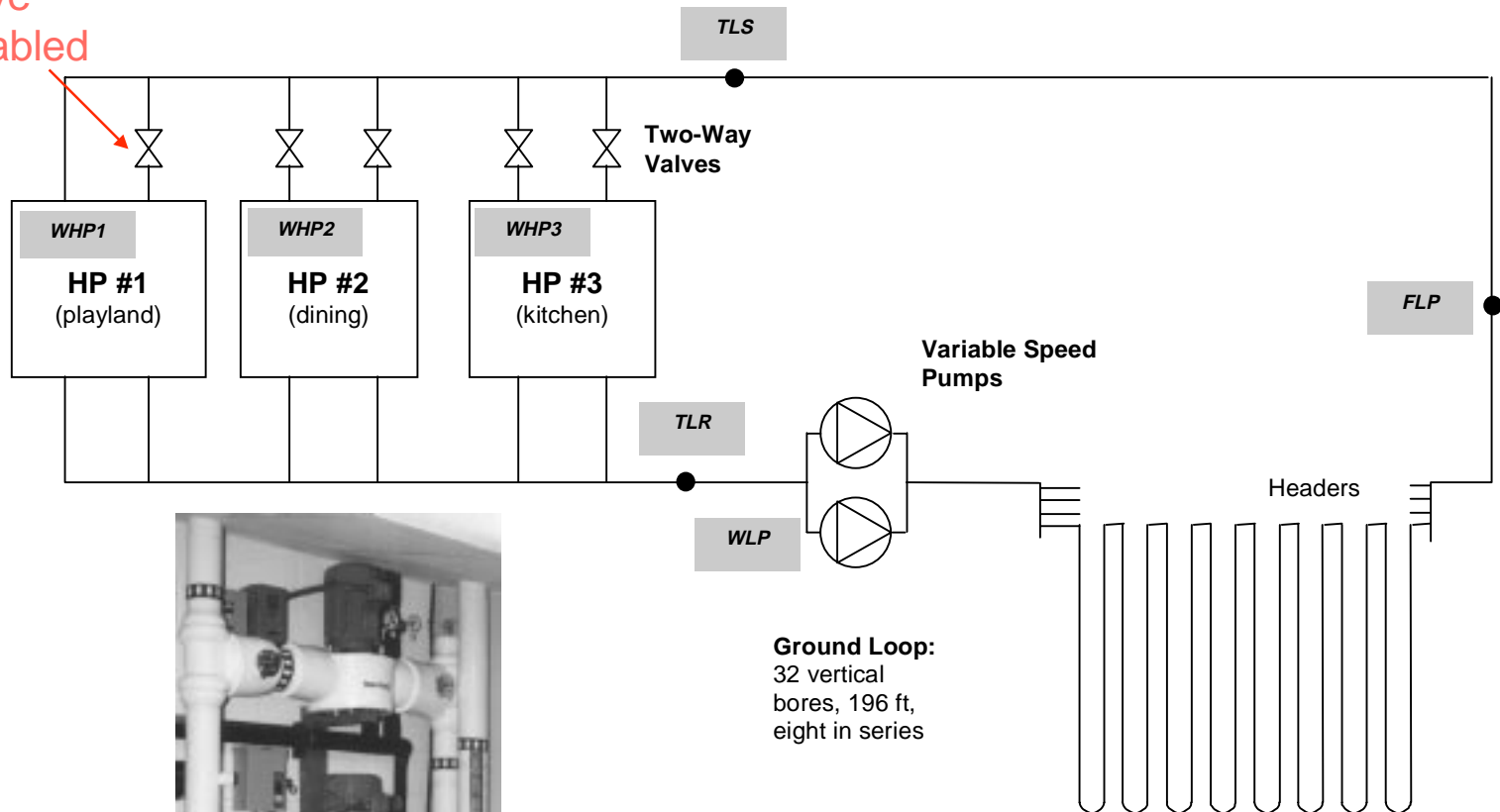
- New McDonalds w/ Playland, 2,711 ft<sup>2</sup>
- Geothermal Loop: 32 bores, 196 ft deep
- 3 units, 33 tons
- 5 Hp loop pump  
w/VSD, 2.7 gpm/ton  
0.15 Hp/ton
- 2-way valves on  
2 units (4 comps)





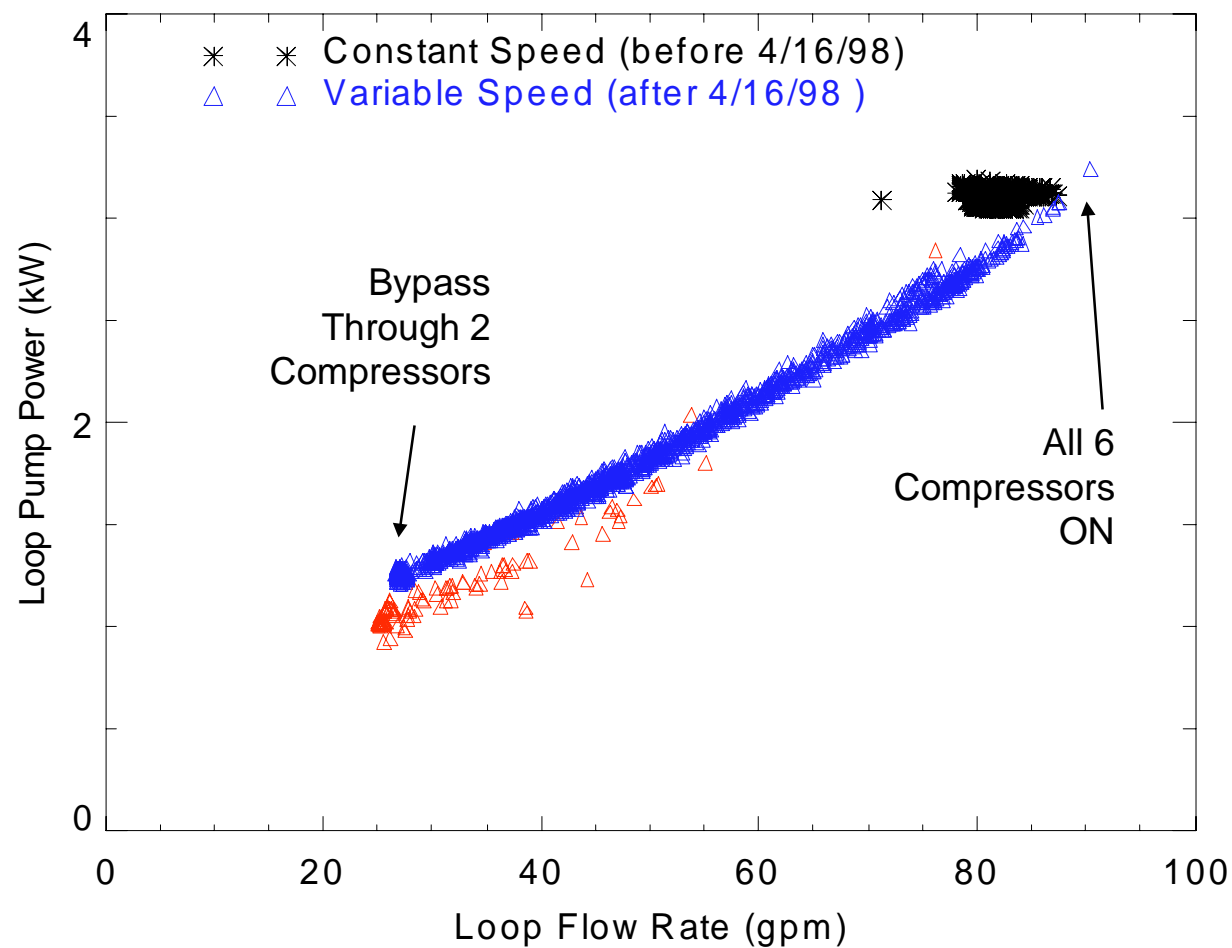
# McDonalds - Pumping System

Valve Disabled

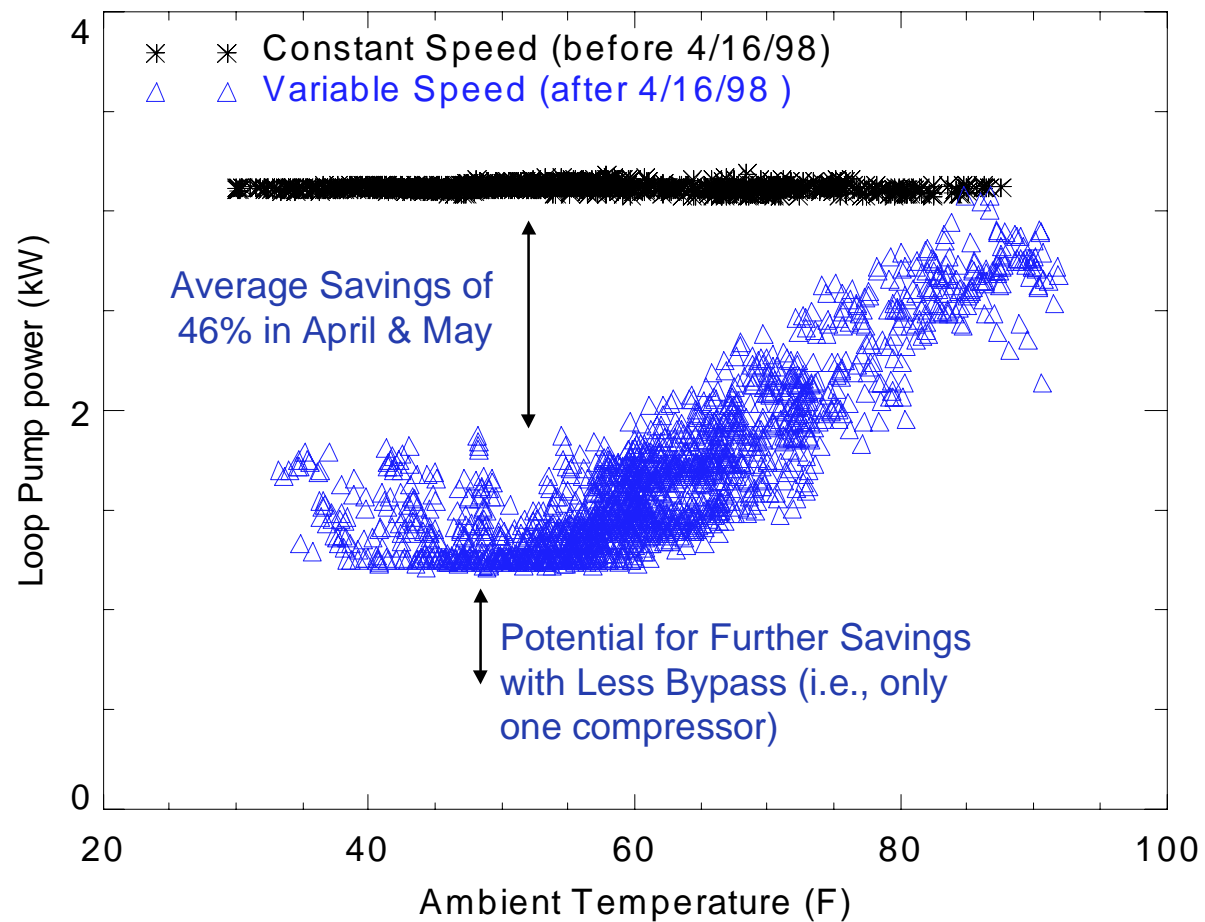


**Ground Loop:**  
32 vertical bores, 196 ft, eight in series

# McDonalds - Pumping System



# McDonalds - Seasonal Impact

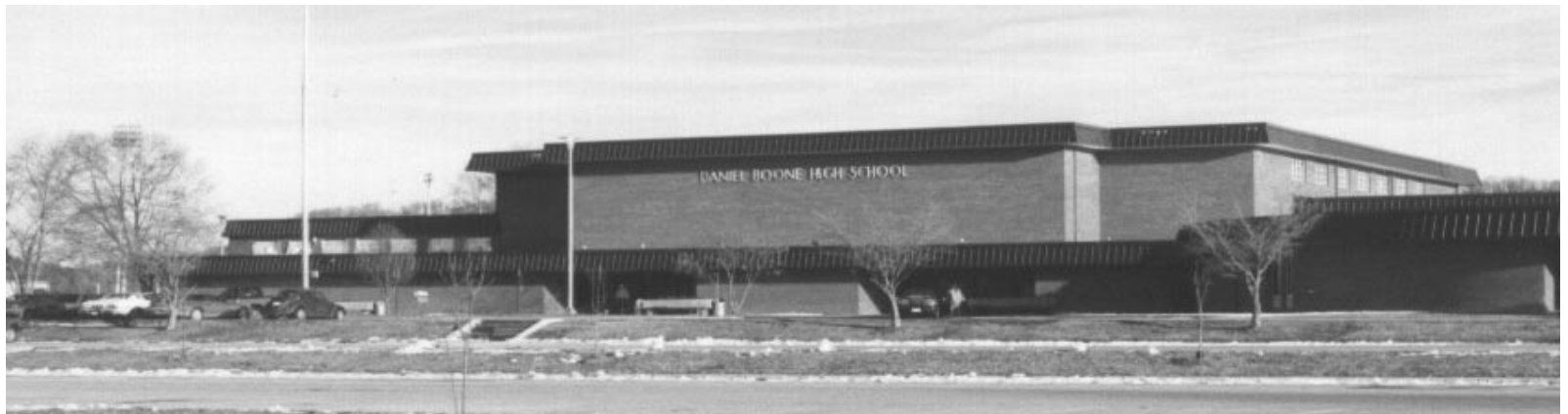


# McDonalds - Summary

- Variable speed pumps turned down to 28% of full flow, but only 54% of full power.
  - Implies loop pressure setpoint may be set too high
  - Or parasitic electrical loads are high
- Decreasing bypass flow to only one valve would also save significant energy

# Daniel Boone High School

- 161,600 ft<sup>2</sup> Facility Renovated in 1995
  - 320 vertical bores, 150 feet deep, 15 ft spacing
  - 120 heat pumps from ¾ to 15 tons, 400 tons total
  - staged pumping system with two 40 Hp, 2-speed motors, 0.2 Hp/ton



# Boone - Pumping System

- Two main circulating pumps
  - Each pump sized at 80% of system capacity

*Stage 1:* one pump @ 1150 rpm

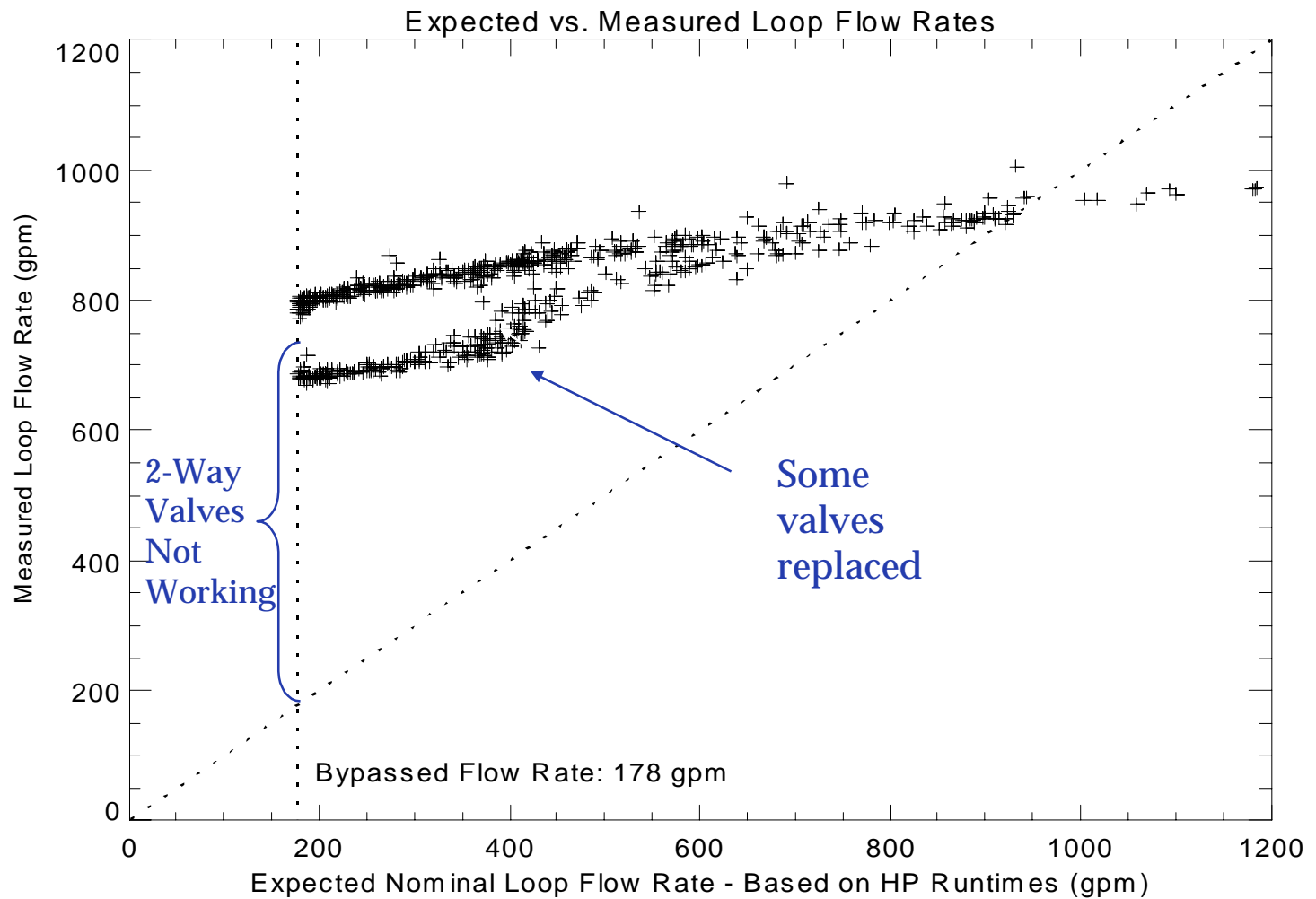
*Stage 2:* one pump @ 1750 rpm

*Stage 3:* two pumps @ 1750 rpm

- Control strategy includes differential pressure and total loop flow
- Two-way valves on each heat pump

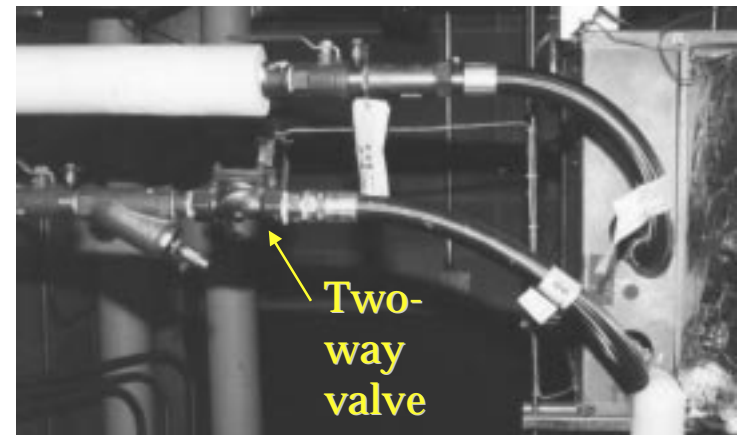


# Boone - Flowrate Too High



# Boone - Observed Performance

- Loop flow rate was not “turning down” as far as expected
  - Intended flow bypass totaled 178 gpm
  - Measured minimum flow about 700 gpm!
- Two-way valves appeared not to be operating as expected
  - Normally-open valves were not closing when HPs were deactivated



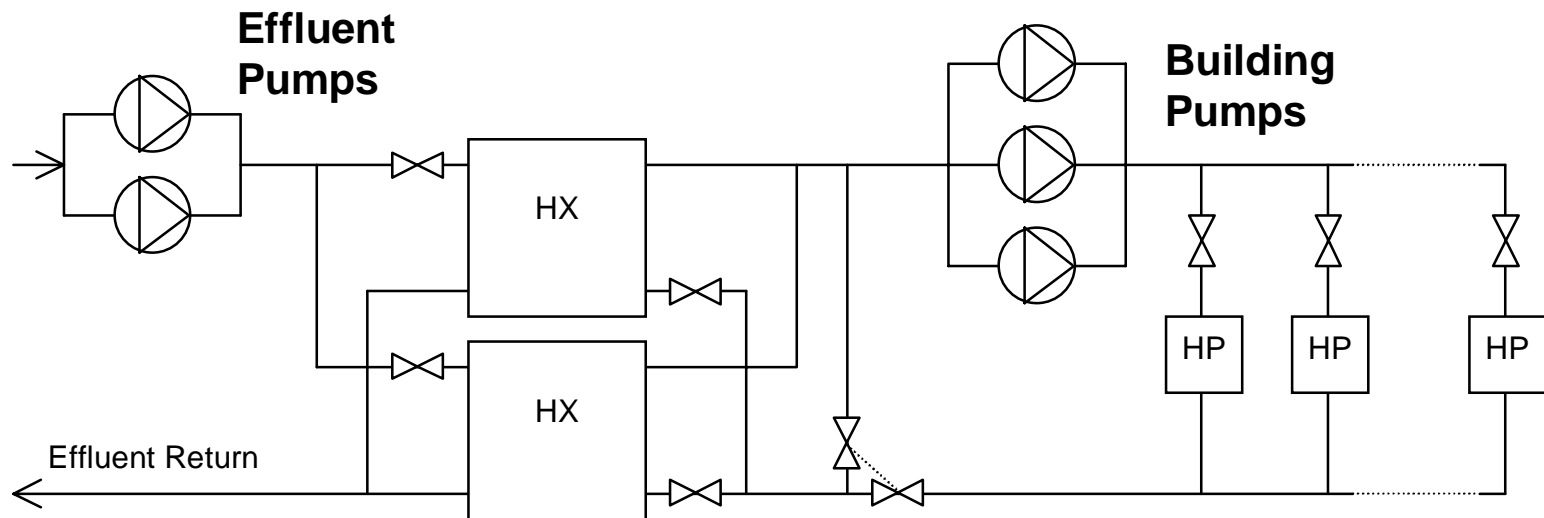


# Boone - Summary

- Two-way valves not working properly on many heat pumps
  - a variety of problems on more than half of all HPs
- Staged pumping approach can be hard to control
  - Currently low speed could not satisfy pressure set point due to bypassed flow

# Water Tower Square

- Heat exchange with treated effluent
- 50+ HPs, 181 tons, (550 tons planned)



# Water Tower - Pumps & HX

## ■ Building loop

- (3) 15 Hp pumps each with VSD
- Two-way valves on HPs
- Valves to bypass HX

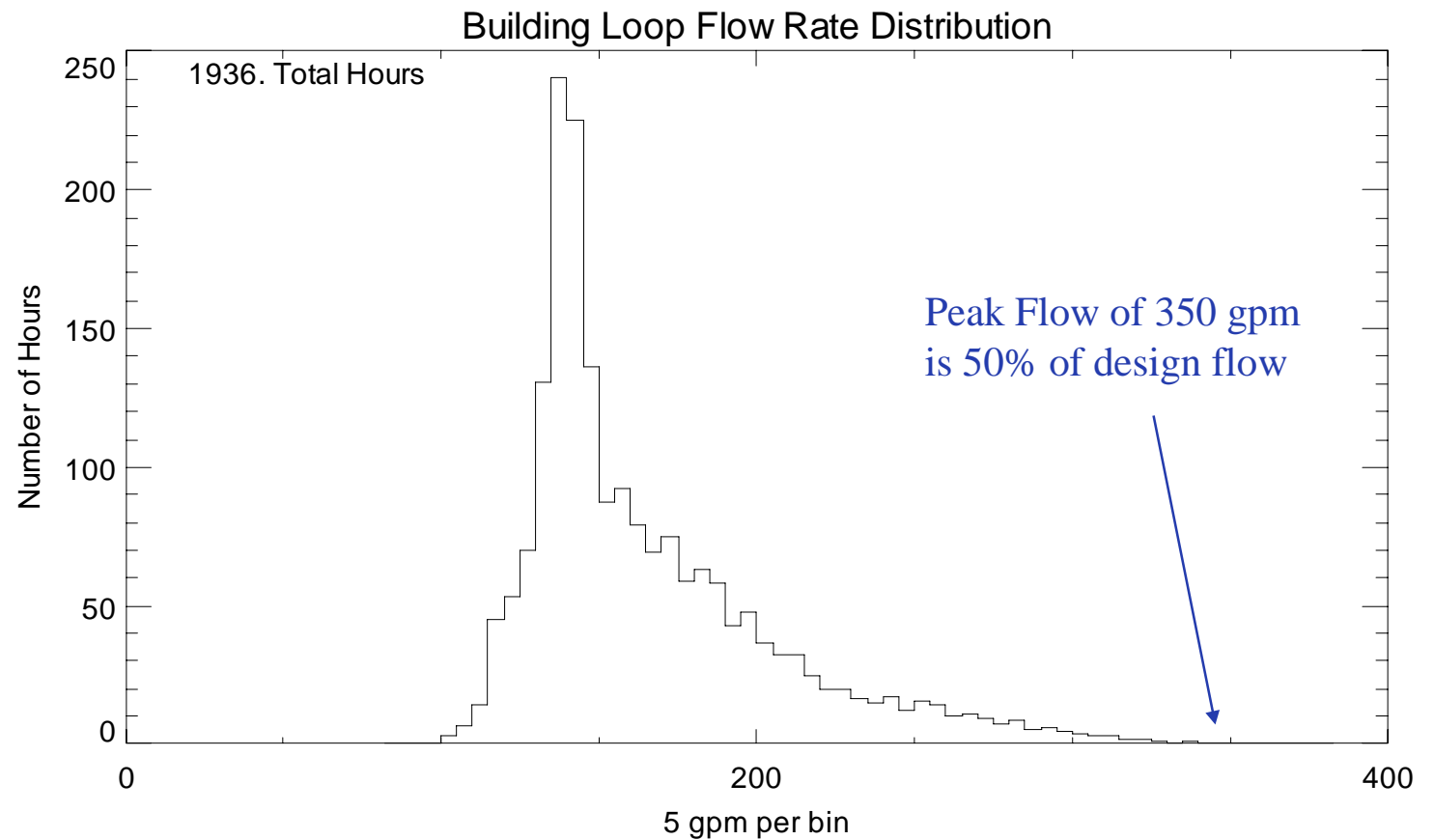


## ■ Effluent / “brown water” loop

- (2) 30 Hp pumps with VSDs
- HX located just outside building

## ■ Controlled on pressure & loop temperature

# Water Tower - Building Flows



# Water Tower - Control Issues

- Building pumps controlled on static not differential pressure
  - Flow turn-down still good, but can be better
  - Two-way valves appear to work now (but had problems at startup)
- Building-side HX bypassed
  - To save pump power but caused freezing problems
  - Bypass unnecessary with proper VSD operation

## Water Tower - Controls (cont.)

- Effluent pumps controlled based on “building loop temperature”
  - But no modulation has been observed
  - Controlling based on HX “approach” might be more effective option
- Working with building owner to evaluate and implement control options

# Annual Pump Performance

|   | <b>Lake-Front<br/>Hotel</b> | <b>McDonalds<sup>1</sup></b> | <b>Daniel Boone<br/>HS</b> |
|---|-----------------------------|------------------------------|----------------------------|
| Nominal Pump Sizing (HP/ton)            | 0.31                        | 0.15                         | 0.20                       |
| Annual Pumping Energy (MWh)             | 38.5                        | 15.2                         | 218.6                      |
| Annual - Constant Speed (MWh)           | 461.3                       | 27.2                         | 394.2                      |
| Variable Flow Energy Savings            | 92%                         | 44%                          | 45%                        |
| Variable Flow Cost Savings <sup>2</sup> | \$25,368                    | \$717                        | \$8,780                    |
| Pump % of All HVAC                      | 11%                         | 18%                          | 42%                        |
| Norm. Pump Power (kWh/ton-hr)           | 0.1                         | 0.58                         | 0.71                       |

Notes: 1 - McDonalds estimated using data from 4/18/98 to 6/8/98. Other sites based on annual data

2 - Annual energy costs assumed to be \$0.06/kWh at Lake-Front Hotel and McDonalds, and \$0.05/kWh at High School.

# Common Themes

- Variable speed pumping
  - Makes up for design shortcomings and operating uncertainties
  - Can reduce energy use by factor of 10
  - Choice of pressure set point is crucial
- Two-way valves - hard to get right
  - Most sites had problems with field wiring
  - High school performed worst due to normally-open valves



# Summary Observations

- Variable flow pumping can cut HVAC energy use in half
  - cut pumping energy by factor of 10
  - equivalent to doubling EER/COP
- Getting two-way valves right in the field is difficult
  - Should valves be factory installed & wired?
- Controls: Components & Setpoints
  - VSDs w/o complicated valving appear best