# Pumps (and Piping)

## Design, Performance and Commissioning Issues

Pump Optimization Options


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Facility Dynamics Engineering


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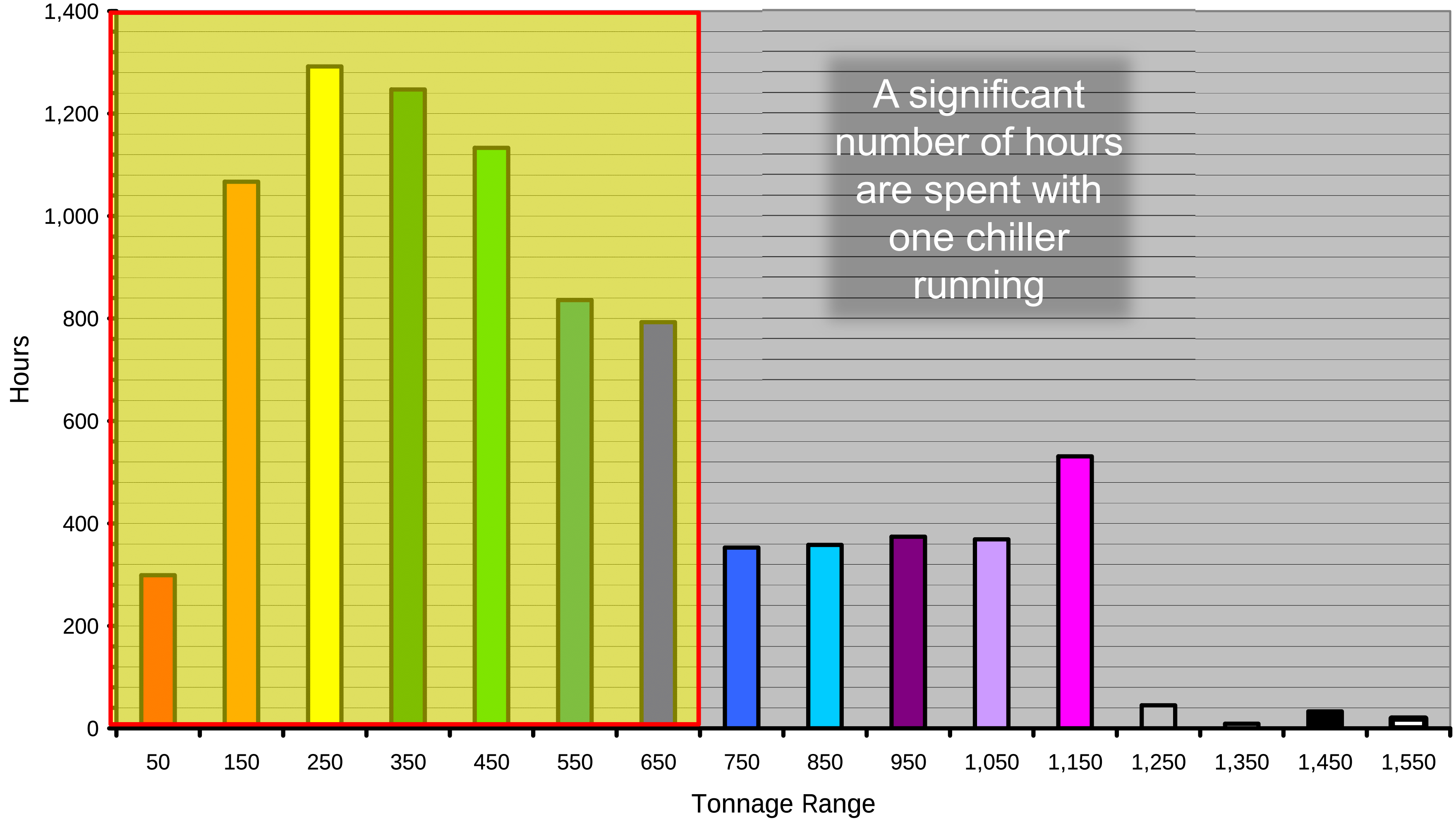
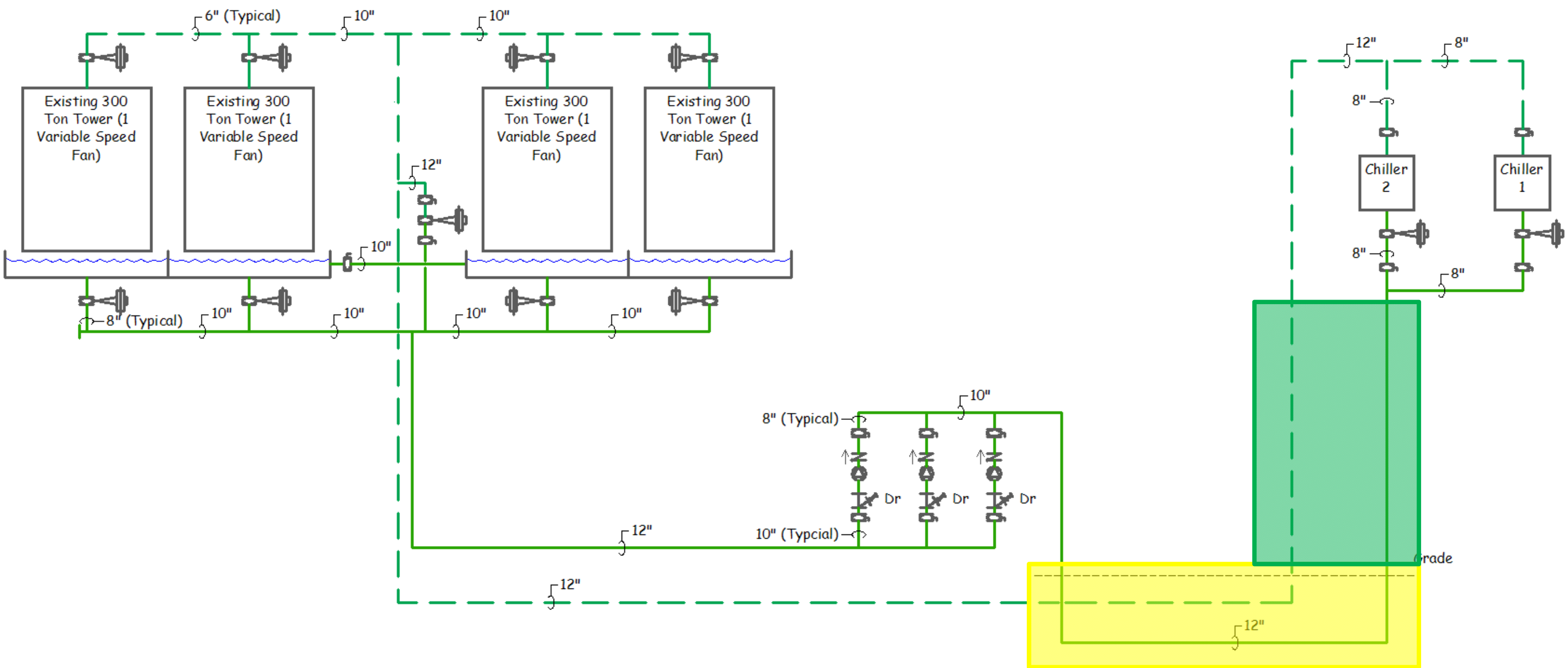
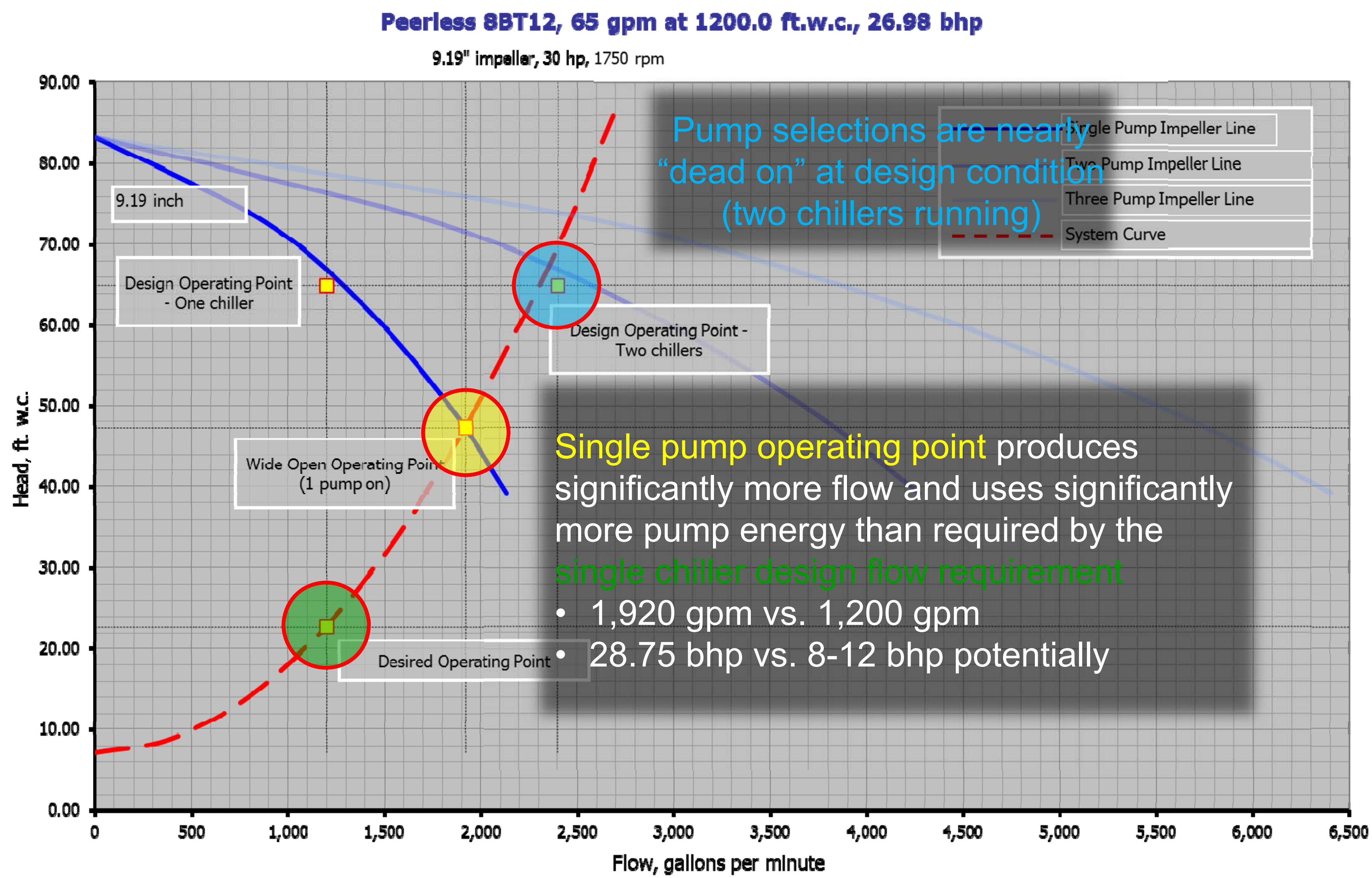
# The San Diego Marriott Marquis and Marina

## San Diego Marina Marriott Chilled Water Plant Hours of Operation at Different Tonnages Based on ECS Data



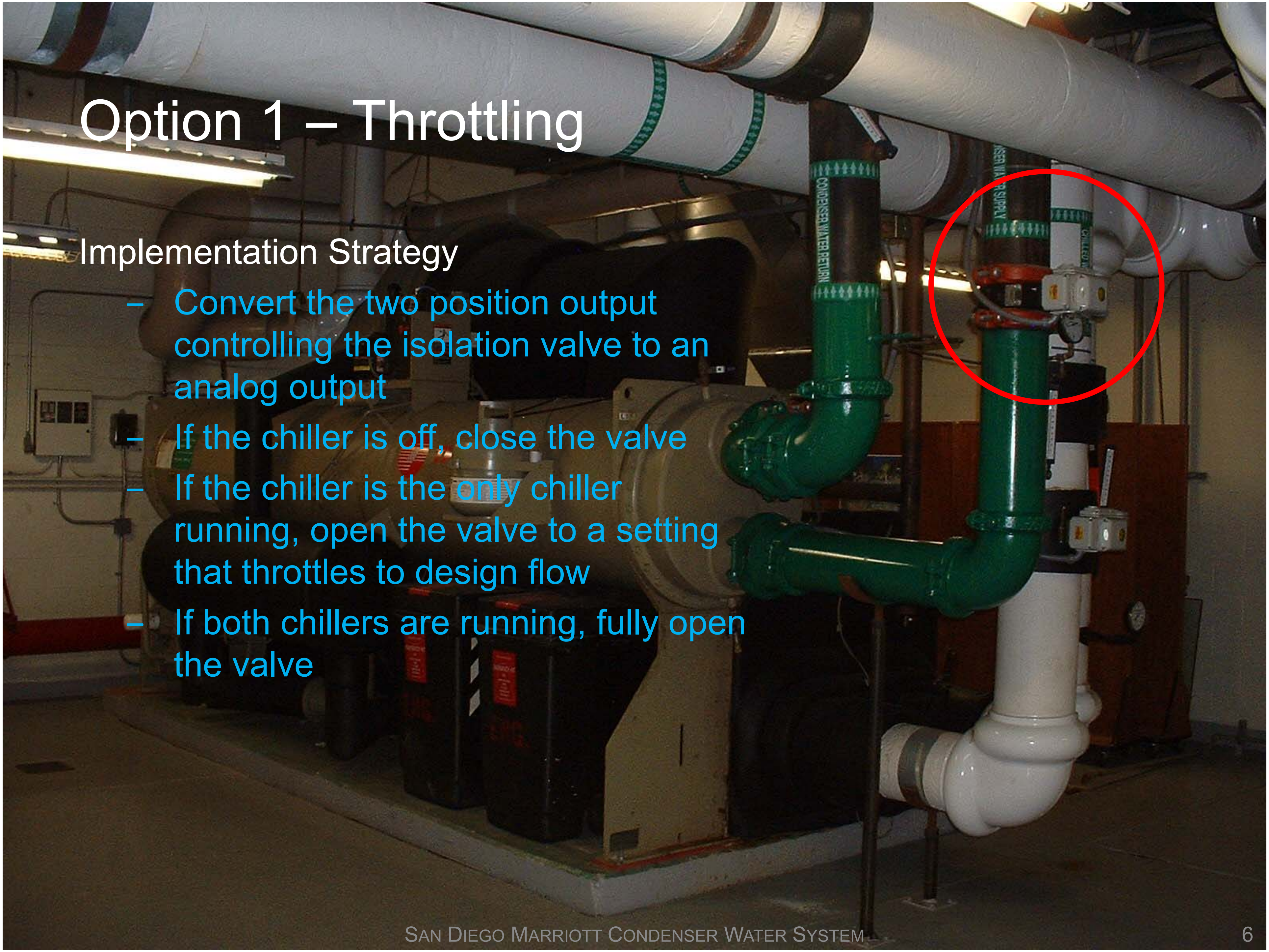



- There are 200 lineal feet between where the pipe goes below grade at the plant and re-emerges at the towers and another 100 feet to the chiller location
- The pressure drop in this long run will vary with the square of the flow




The information on this pump curve was reproduced from the manufacturers certified performance curves for the purposes of analysis and illustration. To verify certified performance for this pump, refer to the manufacturers certified performance curve

# Option 1 – Throttling



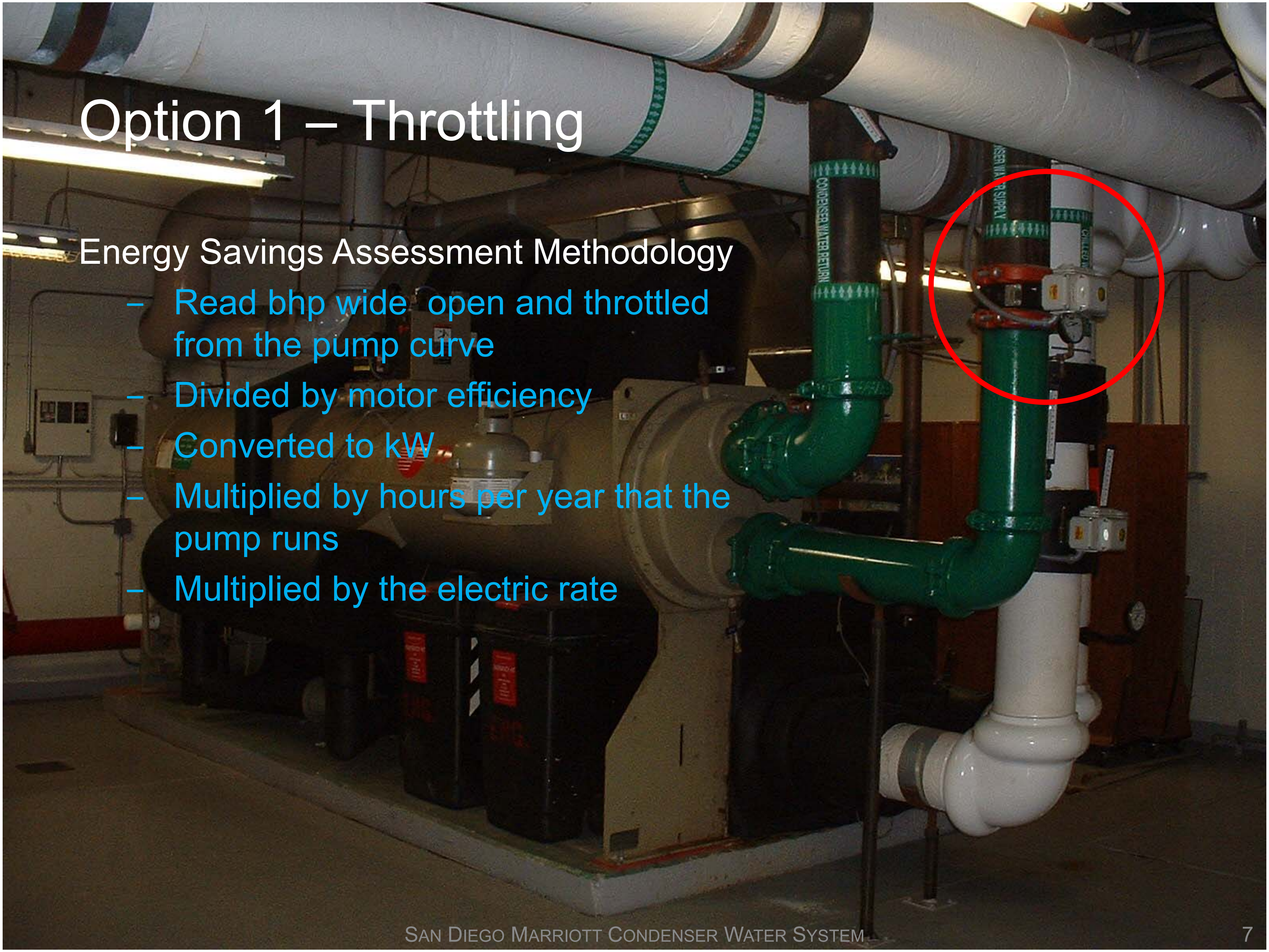

Implementation Strategy

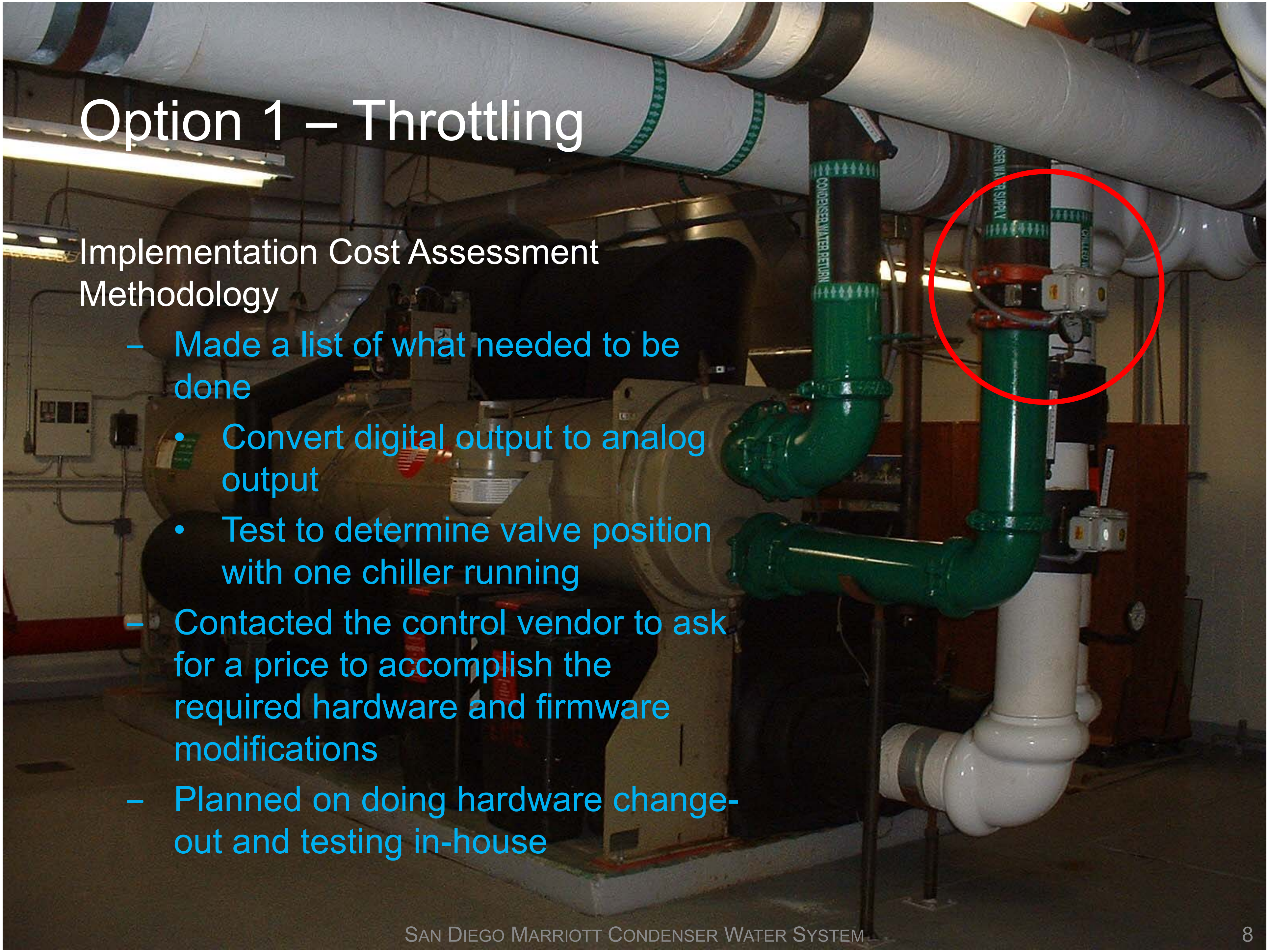
- Convert the two position output controlling the isolation valve to an analog output
- If the chiller is off, close the valve
- If the chiller is the only chiller running, open the valve to a setting that throttles to design flow
- If both chillers are running, fully open the valve

# Option 1 – Throttling

Energy Savings Assessment Methodology

- Read bhp wide  open and throttled from the pump curve
- Divided by motor efficiency
- Converted to kW
- Multiplied by hours per year that the pump runs
- Multiplied by the electric rate

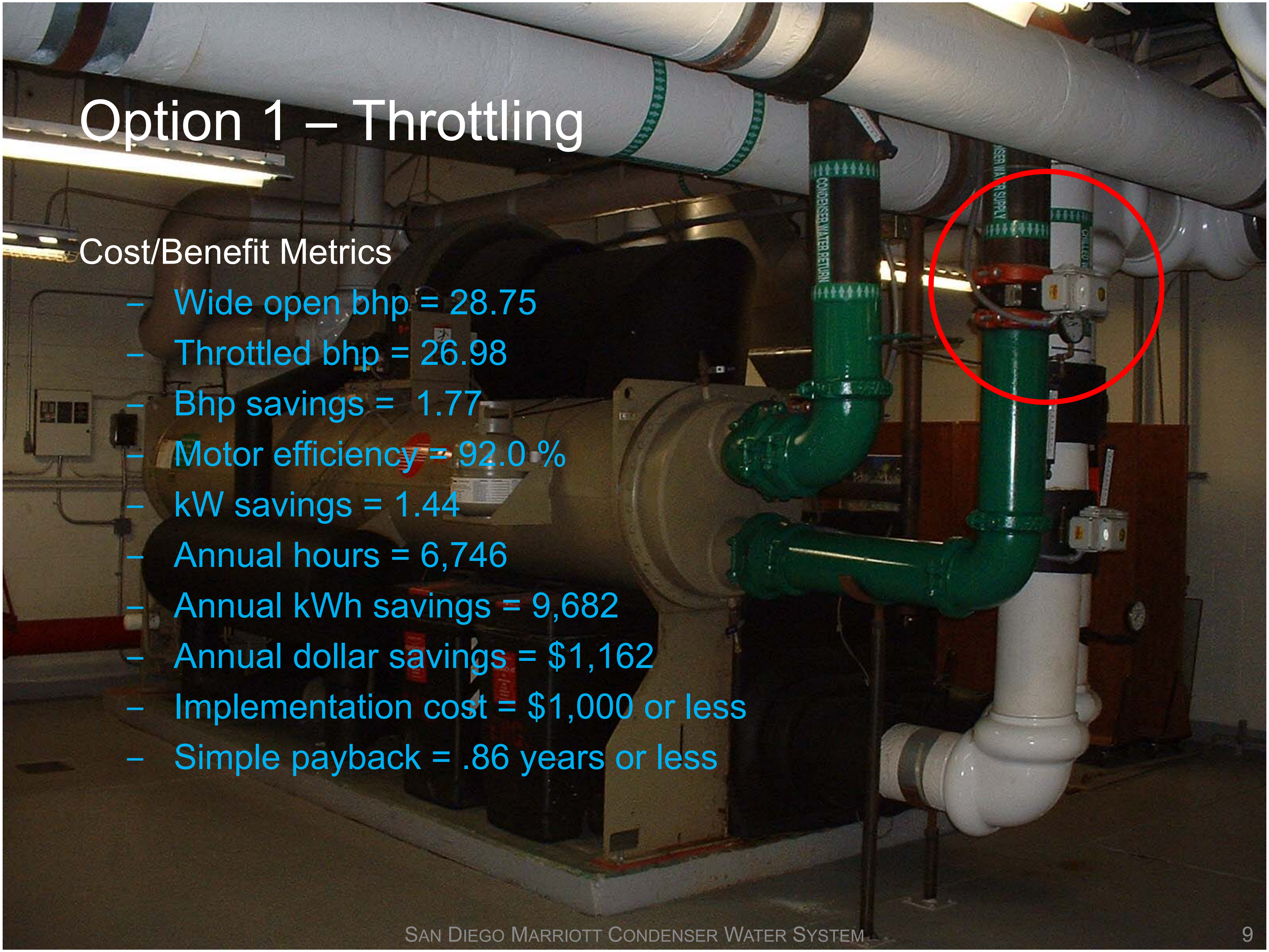





# Option 1 – Throttling

Implementation Cost Assessment Methodology

- Made a list of what needed to be done
  - Convert digital output to analog output
  - Test to determine valve position with one chiller running
- Contacted the control vendor to ask for a price to accomplish the required hardware and firmware modifications
- Planned on doing hardware change-out and testing in-house

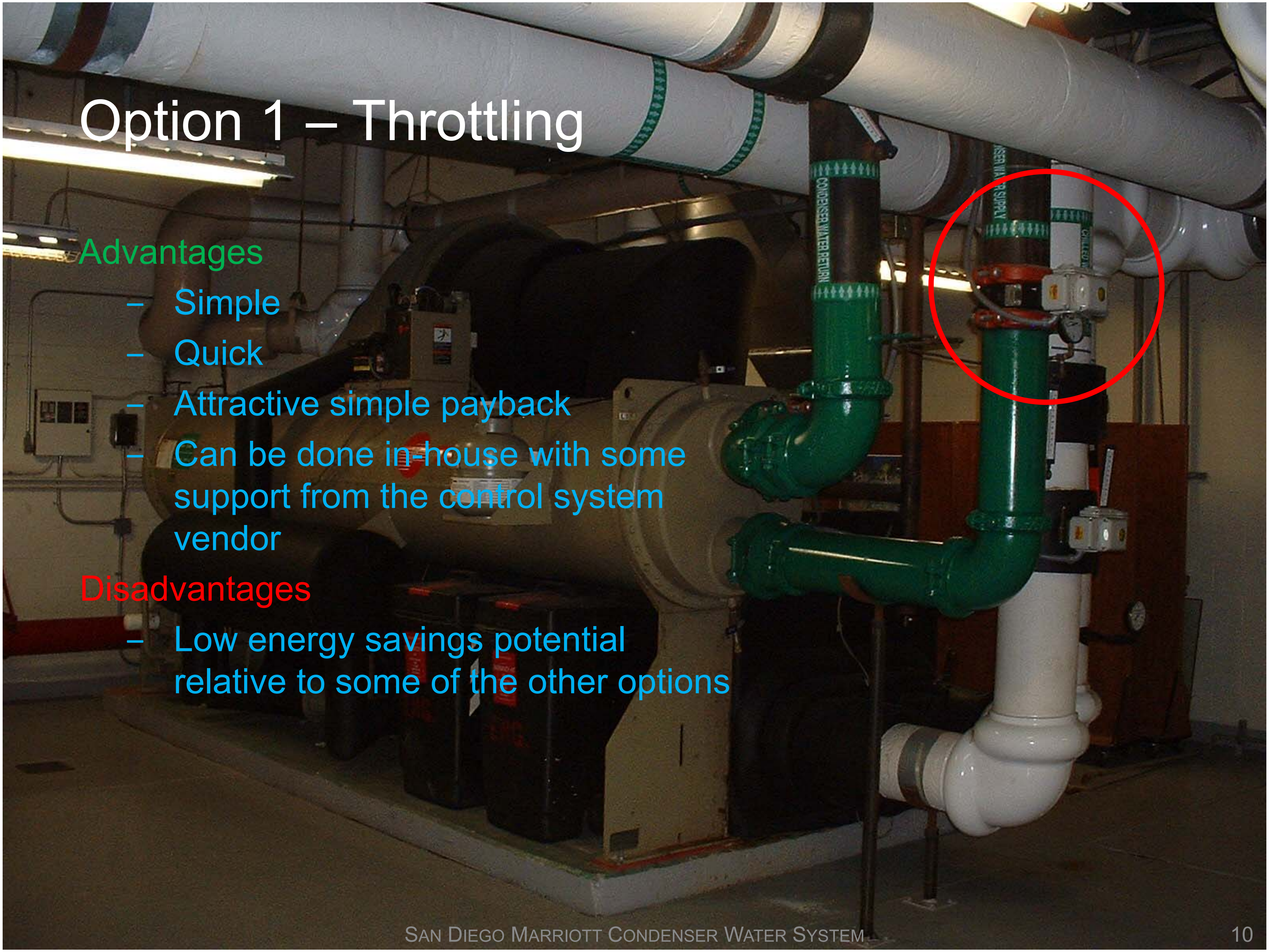



# Option 1 – Throttling

Cost/Benefit Metrics

- Wide open bhp = 28.75
- Throttled bhp = 26.98
- Bhp savings = 1.77
- Motor efficiency = 92.0 %
- kW savings = 1.44
- Annual hours = 6,746
- Annual kWh savings = 9,682
- Annual dollar savings = $1,162
- Implementation cost = $1,000 or less
- Simple payback = .86 years or less

# Option 1 – Throttling

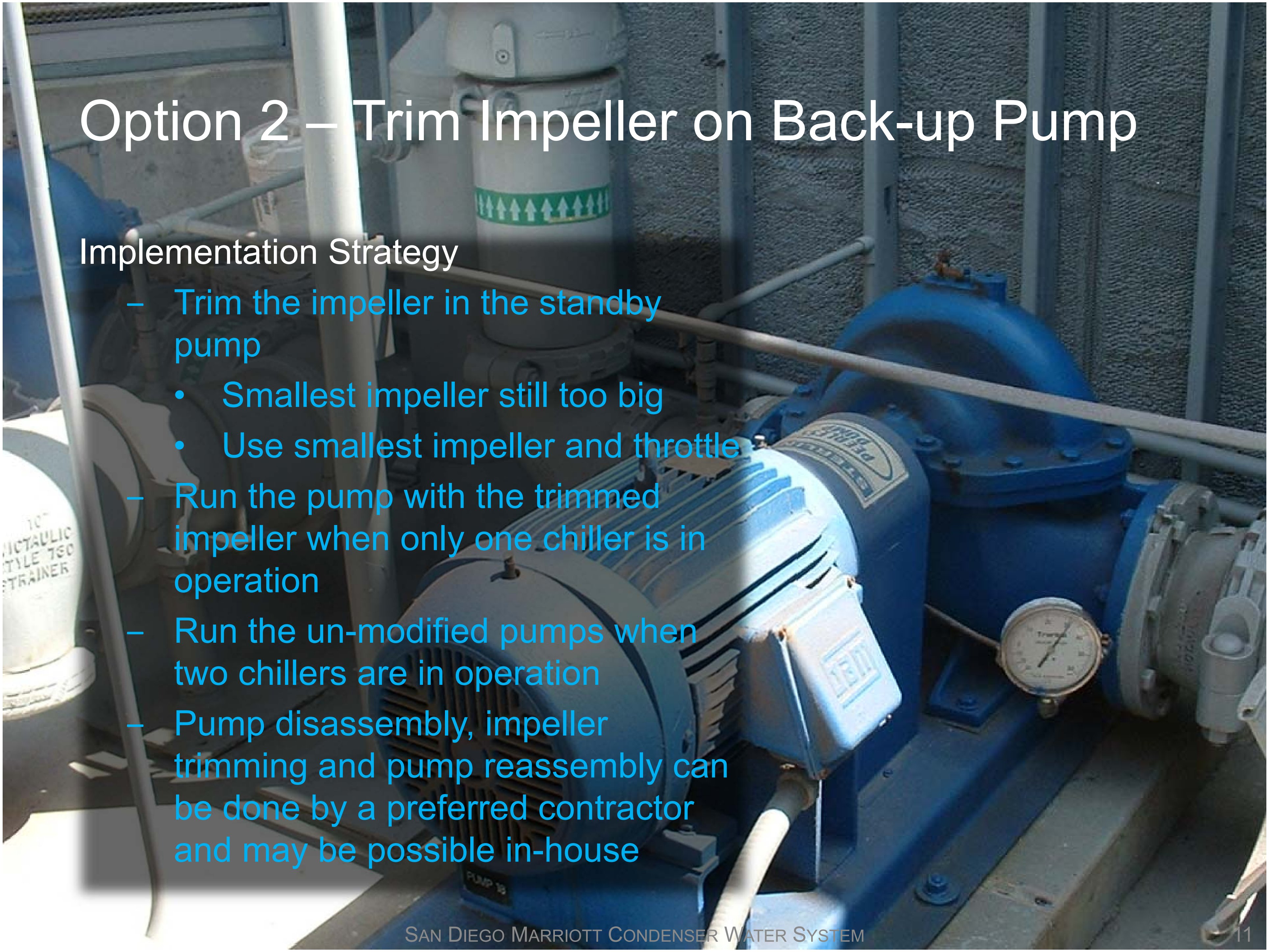



Advantages

- Simple
- Quick
- Attractive simple payback
- Can be done in-house with some support from the control system vendor

Disadvantages

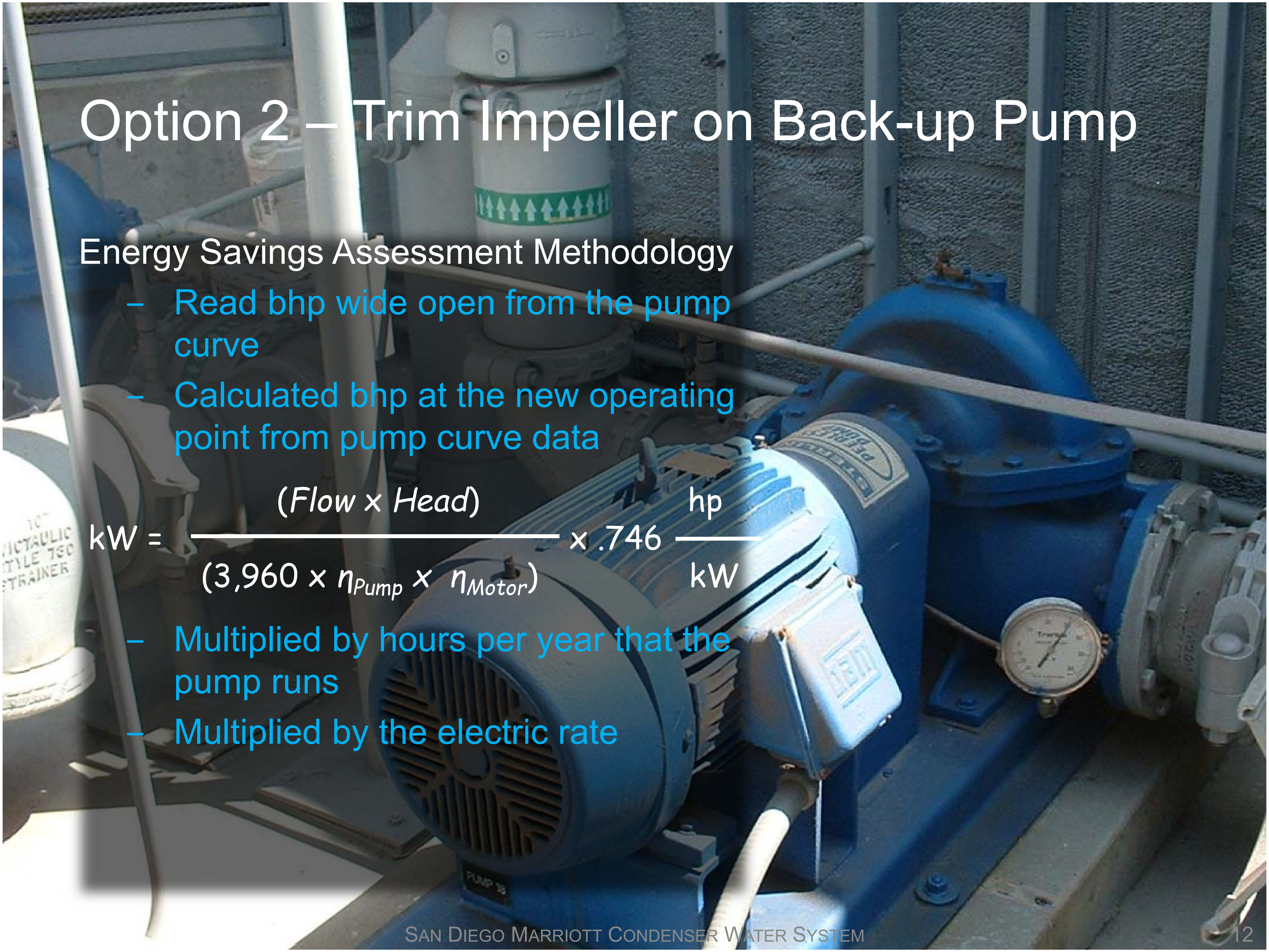
- Low energy savings potential relative to some of the other options



# Option 2 – Trim Impeller on Back-up Pump

Implementation Strategy

- Trim the impeller in the standby pump
  - Smallest impeller still too big
  - Use smallest impeller and throttle
- Run the pump with the trimmed impeller when only one chiller is in operation
- Run the un-modified pumps when two chillers are in operation
- Pump disassembly, impeller trimming and pump reassembly can be done by a preferred contractor and may be possible in-house



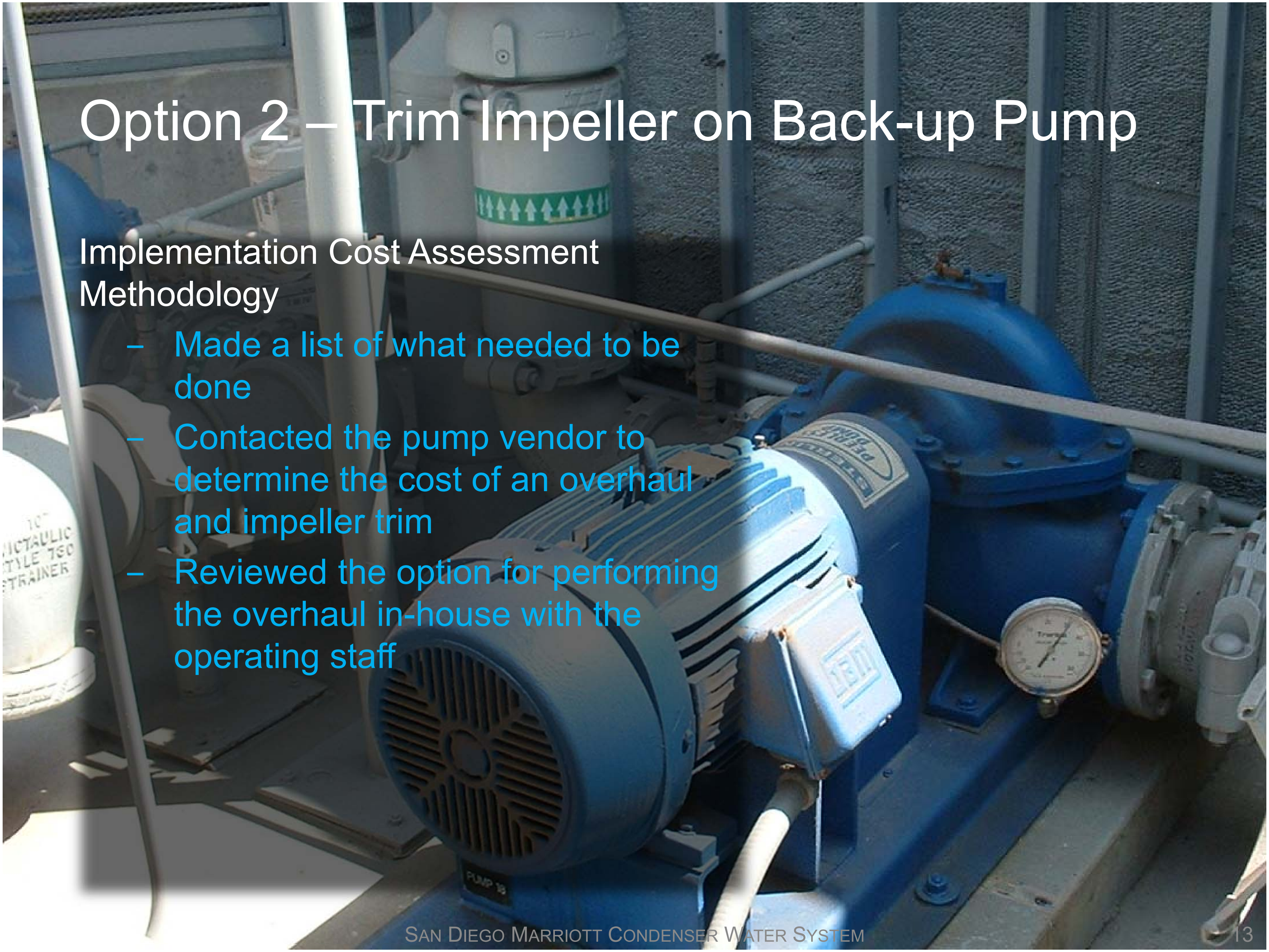
# Option 2 – Trim Impeller on Back-up Pump

Energy Savings Assessment Methodology

- Read bhp wide open from the pump curve
- Calculated bhp at the new operating point from pump curve data

$$kW = \frac{(Flow \times Head)}{(3{,}960 \times \eta_{Pump} \times \eta_{Motor})} \times .746 \frac{hp}{kW}$$

- Multiplied by hours per year that the pump runs
- Multiplied by the electric rate



# Option 2 – Trim Impeller on Back-up Pump

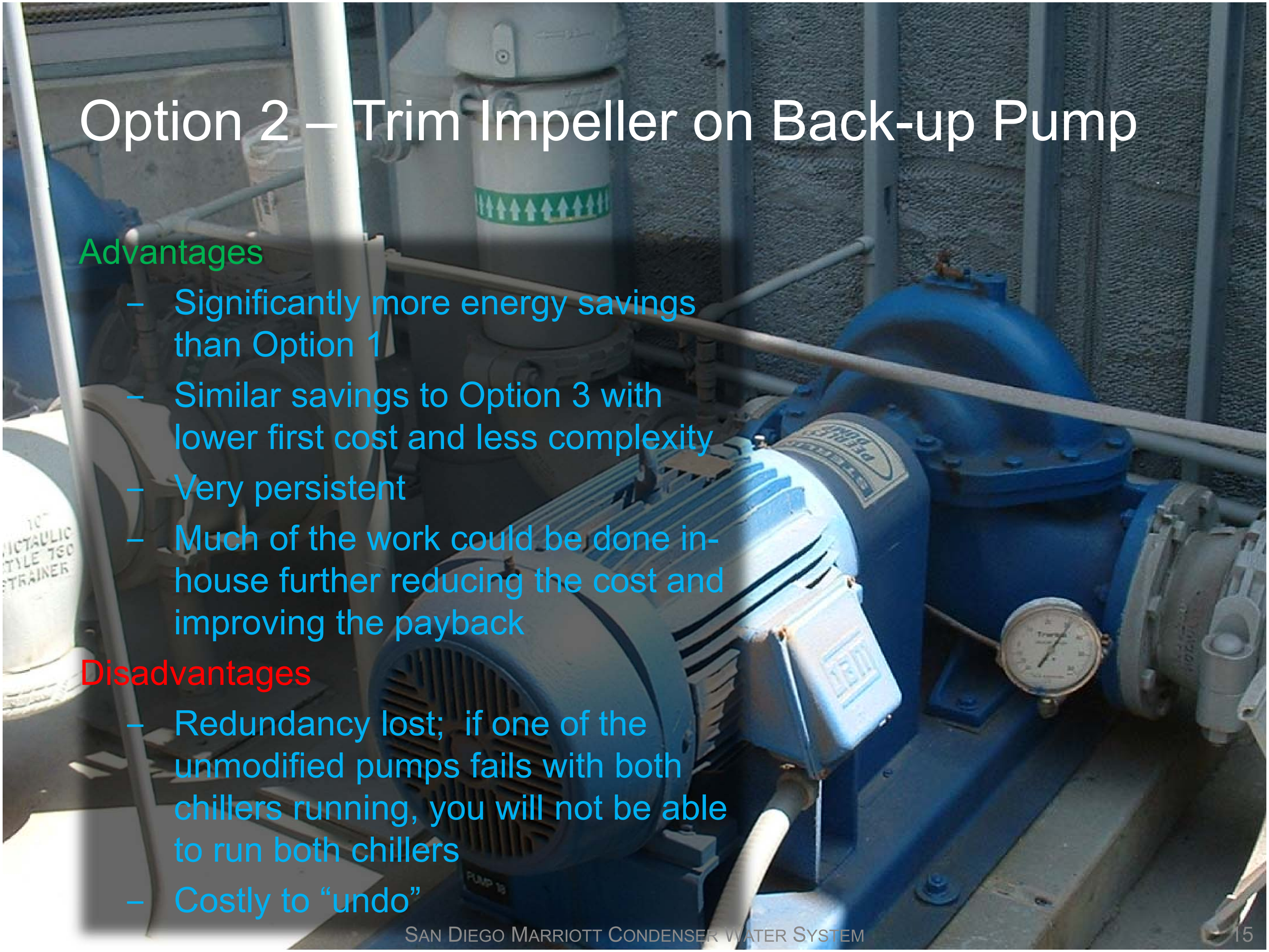
Implementation Cost Assessment Methodology

- Made a list of what needed to be done
- Contacted the pump vendor to determine the cost of an overhaul and impeller trim
- Reviewed the option for performing the overhaul in-house with the operating staff

# Option 2 – Trim Impeller on Back-up Pump

Cost/Benefit Metrics

- Wide open bhp = 28.75
- Trimmed bhp = 17.20
- Bhp savings = 11.55
- Motor efficiency = 92.5%
- kW savings = 9.44
- Annual hours = 6,746
- Annual kWh savings = 63,694
- Annual dollar savings = $7,643
- Implementation cost = $5,000 or less
- Simple payback = .65 years or less



# Option 2 – Trim Impeller on Back-up Pump

Advantages

- Significantly more energy savings than Option 1
- Similar savings to Option 3 with lower first cost and less complexity
- Very persistent
- Much of the work could be done in-house further reducing the cost and improving the payback

Disadvantages

- Redundancy lost; if one of the unmodified pumps fails with both chillers running, you will not be able to run both chillers
- Costly to “undo”

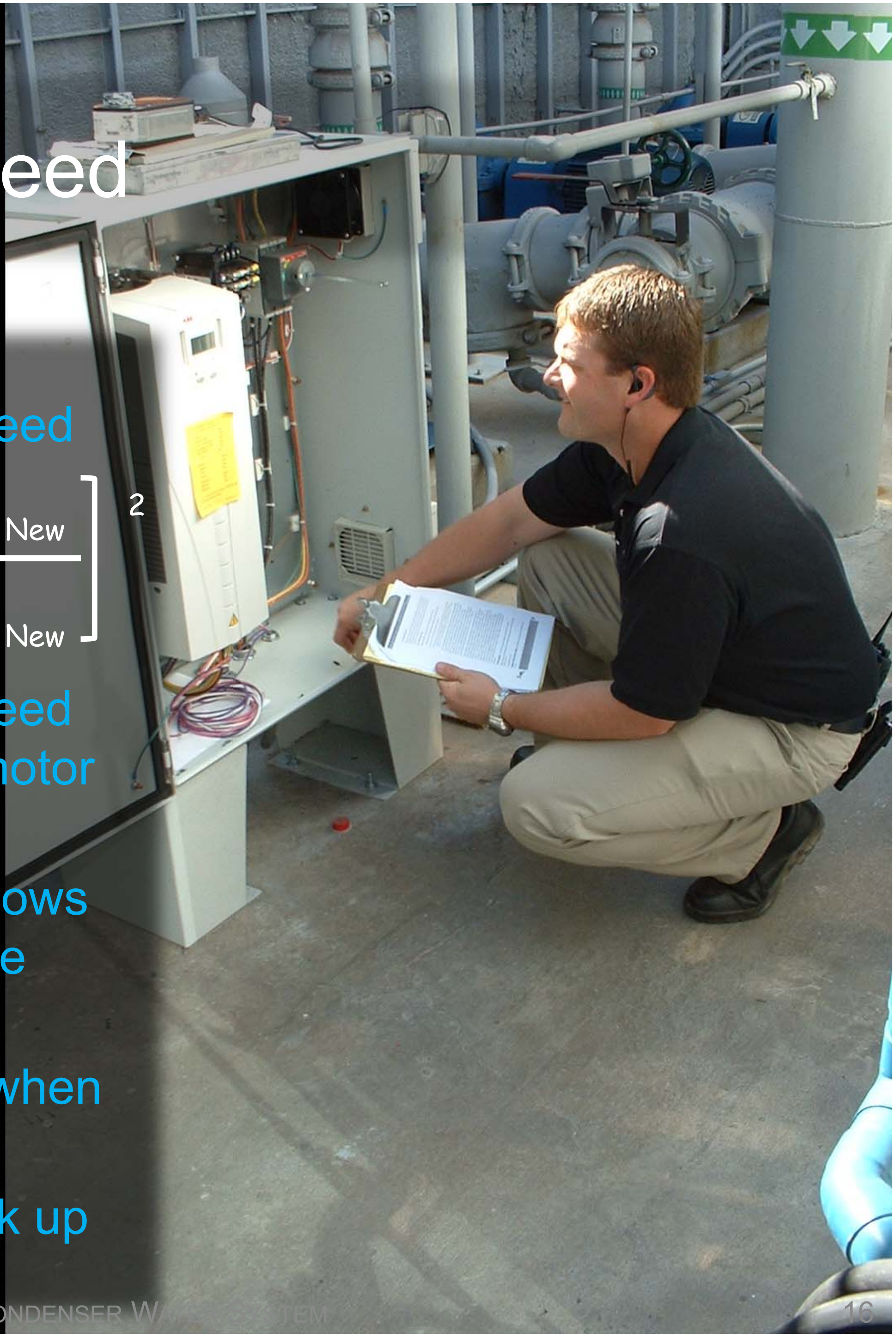
# Option 3 – Reduce Speed

Implementation Strategy

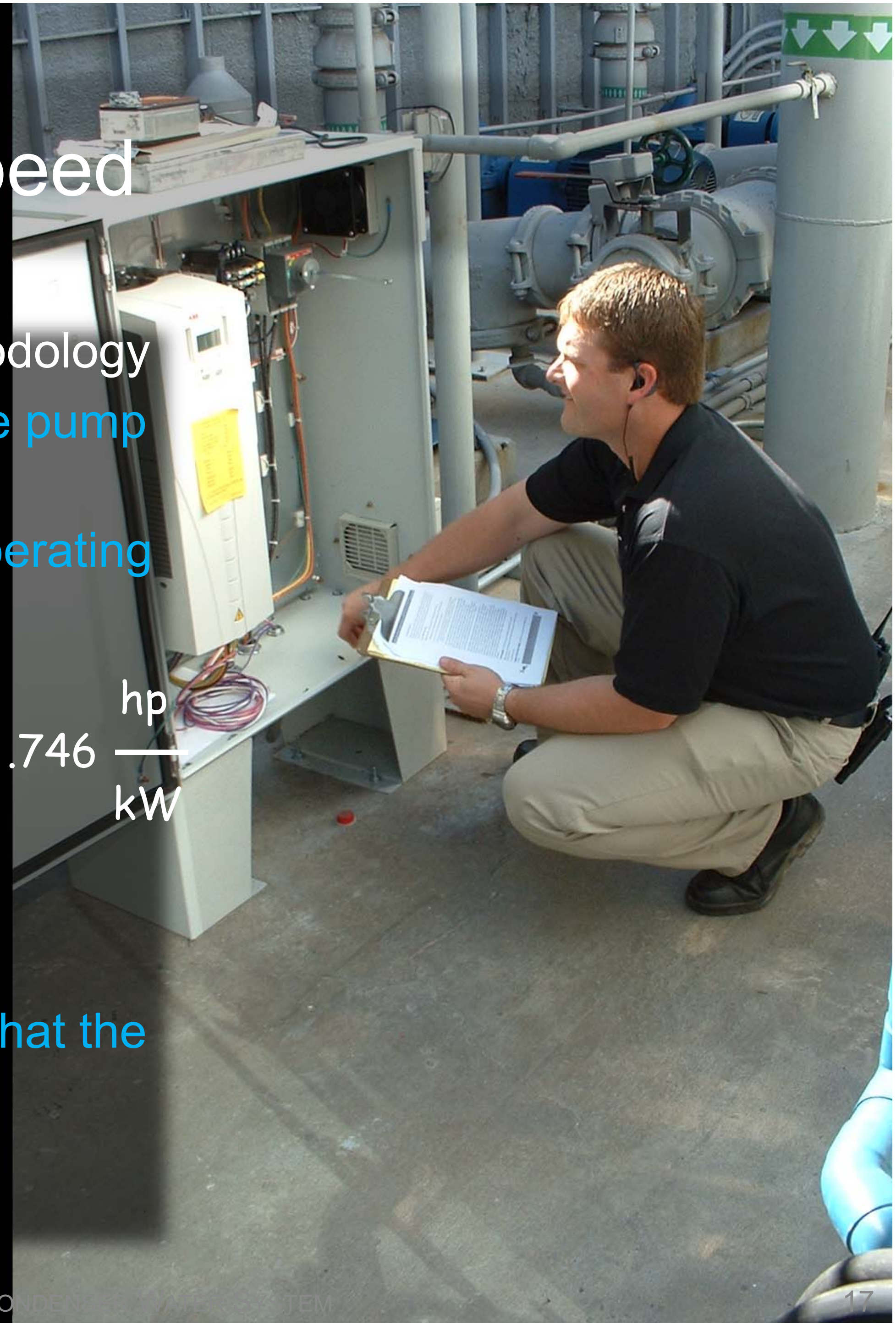
- Affinity laws identify target speed

$$Speed_{New} = Speed_{Old} \times \left[ \frac{Flow_{New}}{Flow_{New}} \right]^{2}$$

- Redundancy and required speed eliminate speed change via motor change option
- Variable speed drive (VSD) slows the pump down when only one chiller is running
- Both fixed speed pumps run when two chillers run
- VSD runs at full speed to back up fixed speed pumps



# Option 3 – Reduce Speed



Energy Savings Assessment Methodology

- Read bhp wide open from the pump curve
- Calculated bhp at the new operating point from pump curve data

$$\text{kW} = \frac{(\textit{Flow} \times \textit{Head})}{(3{,}960 \times \eta_{Pump} \times \eta_{Motor} \times \eta_{Drive})} \times .746\ \frac{\text{hp}}{\text{kW}}$$

- Divided by motor efficiency
- Converted to kW
- Multiplied by hours per year that the pump runs
- Multiplied by the electric rate

# Option 3 – Reduce Speed

Implementation Cost Assessment Methodology

- Made a list of what needed to be done
  - Furnish and install a VFD
  - Interlock with existing control system
- Perform control work in-house
- Develop a RFP and price VFDs for installation by an electrician

# Option 3 – Reduce Speed

Cost/Benefit Metrics

- Wide open bhp = 28.75
- Reduced speed bhp = 9.19
- Bhp savings = 19.56
- Motor efficiency = 91.0%
- VFD efficiency = 92.0%
- kW savings = 15.12
- Annual hours = 6,746
- Annual kWh savings = 102,012
- Annual dollar savings = $12,241
- Implementation cost = $12,850
- Simple payback = 1.05 years

# Option 3 – Reduce Speed

Advantages

- 2nd largest energy savings
- Attractive simple payback
- Preserves redundancy

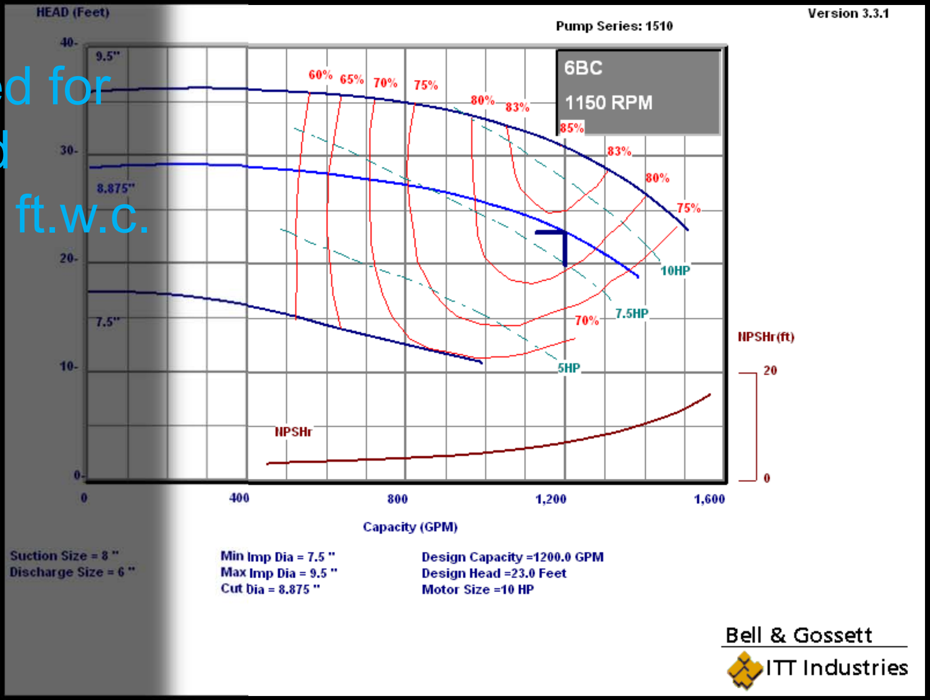
Disadvantages

- Complex
- 2nd most expensive
- Less persistent

# Option 4 – Replace the Pump

Implementation Strategy

- Select and install a pump rated for peak efficiency at the required conditions of 1,200 gpm at 23 ft.w.c.



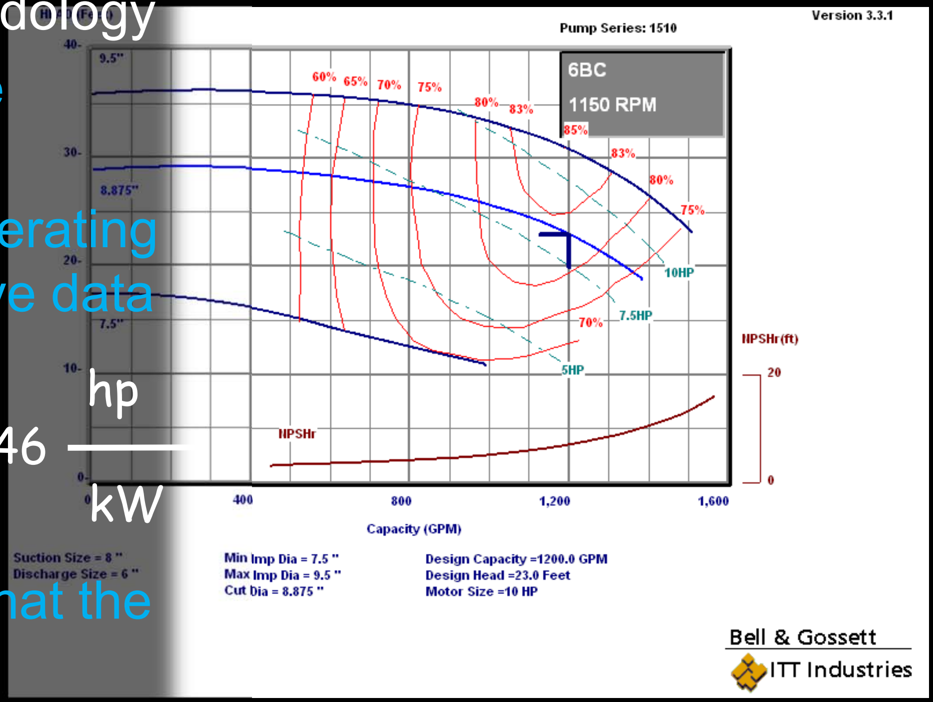
# Option 4 – Replace the Pump

Energy Savings Assessment Methodology

- Read bhp wide open from the existing pump curve
- Calculated bhp at the new operating point from the new pump curve data

$$kW = \frac{(Flow \times Head)}{(3{,}960 \times \eta_{Pump} \times \eta_{Motor})} \times .746 \frac{hp}{kW}$$

- Multiplied by hours per year that the pump runs
- Multiplied by the electric rate



# Option 4 – Replace the Pump

Implementation Cost Assessment Methodology

- Made a list of what needed to be done
  - Pump and trim
  - Pipe
  - Valves
  - Fittings
  - Welds/labor
  - Wire and conduit
  - Electrical gear
- Use R.S. Means or other resources to assess the cost

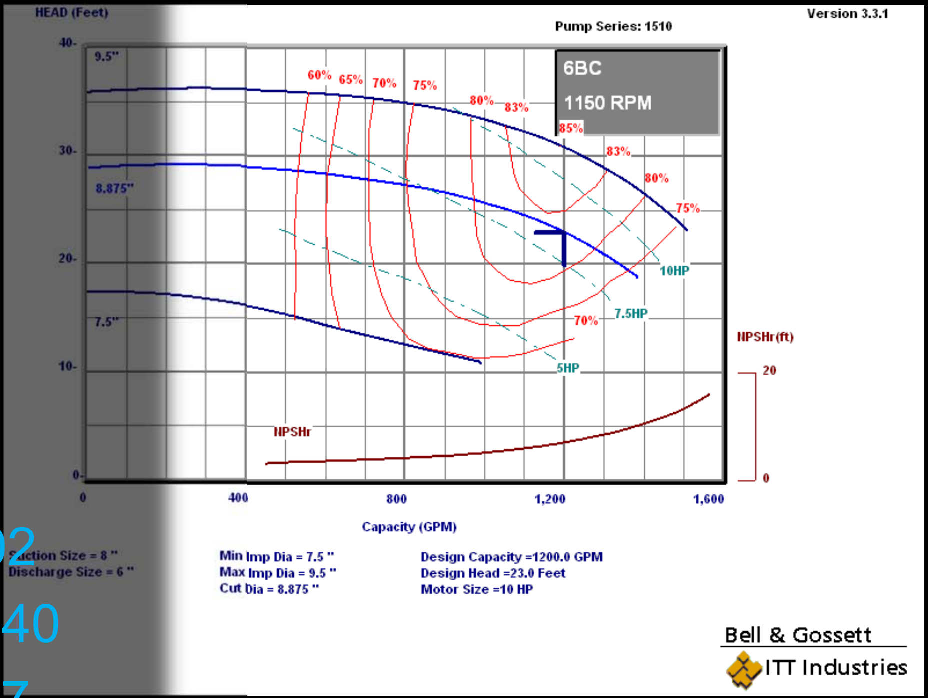
**Cost Projection for Adding a Redundant Pump**

| No. | Description | Quant. | Units | Material: Unit Cost, $ | Material: Total Cost, $ | Outside Contractor Labor: Rate, $ per hour | Outside Contractor Labor: Unit Hours | Outside Contractor Labor: Total Hours | Outside Contractor Labor: Total Cost, $ |
|---|---|---|---|---|---|---|---|---|---|
| | Pump | 1 | ea | $10,600.00 | $10,600 | $43.75 | 48.0000 | 48.0 | $2,100 |
| | 8" suction Diffusser | 1 | ea | $1,775.00 | $1,775 | $43.75 | 9.6000 | 9.6 | $420 |
| | 8" butterfly valve | 2 | ea | $320.00 | $640 | $43.75 | 5.3330 | 10.7 | $467 |
| | Butterfly valve operator | 2 | ea | With valve | | With valve | | 0.0 | $0 |
| | 8" check valve | 1 | ea | $950.00 | $950 | $43.75 | 5.3330 | 5.3 | $233 |
| | 8" flex connector | 2 | ea | $310.00 | $620 | $43.75 | 2.0000 | 4.0 | $175 |
| | 8" pipe flanges | 12 | ea | $92.50 | $1,110 | $43.75 | 3.4290 | 41.1 | $1,800 |
| | Flange gaskets and bolt sets | 12 | ea | $16.20 | $194 | $43.75 | 1.6000 | 19.2 | $840 |
| | 8" pipe | 20 | ft | $48.94 | $979 | $43.75 | 0.8280 | 16.6 | $725 |
| | 10" x 8" reducing tee | 2 | ea | $558.00 | $1,116 | $43.75 | 12.0000 | 24.0 | $1,050 |
| | 8" 45 degree elbow | 2 | ea | $115.00 | $230 | $43.75 | 6.4000 | 12.8 | $560 |
| | Gauge valves (1/4" ball valves) | 3 | ea | $10.30 | $31 | $43.75 | 0.3330 | 1.0 | $44 |
| | Vent and drain (3/4" ball valves) | 2 | ea | $16.95 | $34 | $43.75 | 0.4000 | 0.8 | $35 |
| | Pressure gauge | 1 | ea | $167.00 | $167 | $43.75 | 0.2500 | 0.3 | $11 |
| | Pipe insulation | 0 | ft | $4.78 | $0 | $38.76 | 0.1780 | 0.0 | $0 |
| | Pump/suction diffusser insulation | 0 | sq.ft | $4.24 | $0 | $38.76 | 0.1680 | 0.0 | $0 |
| | Fitting insulation - flanges | 0 | ea | $19.12 | $0 | $38.76 | 0.7120 | 0.0 | $0 |
| | Fitting insulation - special fittings | 0 | ea | $19.12 | $0 | $38.76 | 0.7120 | 0.0 | $0 |
| | Fitting insulation - 8" elbow | 0 | ea | $14.34 | $0 | $38.76 | 0.5340 | 0.0 | $0 |
| | Fitting insulation - 10" tee | 0 | ea | $15.45 | $0 | $38.76 | 0.6000 | 0.0 | $0 |
| | 1" conduit | 50 | ft | $3.66 | $183 | $45.53 | 0.1230 | 6.2 | $280 |
| | #8 gauge wire | 200 | ft | $0.41 | $81 | $45.53 | 0.0100 | 2.0 | $91 |
| | Pull box | 2 | ea | $26.00 | $52 | $45.53 | 1.4450 | 2.9 | $132 |
| | Variable speed drive | 0 | ea | $13,930.00 | $0 | $45.53 | 51.2820 | 0.0 | $0 |
| | Panel board switch | 1 | ea | $1,100.00 | $1,100 | $45.53 | 2.0000 | 2.0 | $91 |
| | VFD factory start-up | 1 | ea | $0.00 | $0 | $91.06 | 4.0000 | 4.0 | $364 |
| | Pad | 1 | ea | $150.00 | $150 | $37.81 | 1.6000 | 1.6 | $61 |
| | Grouting | 1 | ea | $75.00 | $75 | $37.81 | 1.6000 | 1.6 | $61 |
| | Alignment | 1 | ea | $25.00 | $25 | $91.06 | 2.0000 | 2.0 | $182 |
| | Start stop point | 1 | ea | $330.00 | $330 | With material | | 0.0 | $0 |
| | Proof of operation point | 1 | ea | $850.00 | $850 | With material | | 0.0 | $0 |
| | Speed command point | 1 | ea | $330.00 | $330 | With material | | 0.0 | $0 |
| | Network interface for diagnostics | 1 | ea | $550.00 | $550 | With material | | 0.0 | $0 |
| | Verification checks and start-up | 1 | lot | $0.00 | $0 | $125.00 | 2.0000 | 2.0 | $250 |
| | | | | | $0 | | | 0.0 | $0 |
| TOTALS | | | | | **$22,172** | | | **218** | **$9,970** |
| **TOTAL - All Cost Components** | | | | | **$32,142** | | | | |
| **TAX** | | **5.00%** | | | **$1,109** | | | | |
| **TOTAL DIRECT COST** | | | | | **$33,251** | | | | |
| **CONTINGENCIES** | | | | | | | | | |
| | **Design** | **0.00%** | | | **$0** | | | | |
| | **Construction** | **3.00%** | | | **$998** | | | | |
| **CONTRACTOR'S MARK-UPS** | | | | | | | | | |
| | **Overhead** | **10.00%** | | | **$3,425** | | | | |
| | **Profit** | **5.00%** | | | **$1,884** | | | | |
| **Net Mark-up with contingencies** | | **123.07%** | | | | | | | |
| **GRAND TOTAL** | | | | | **$39,557** | | | | |

# Option 4 – Replace the Pump

Cost/Benefit Metrics

- Wide open bhp = 28.75
- New pump bhp = 8.37
- Bhp savings =  20.38
- Motor efficiency = 92.1%
- kW savings = 18.46
- Annual hours = 6,746
- Annual kWh savings = 124,502
- Annual dollar savings = $14,940
- Implementation cost = $39,577
- Simple payback = 2.65 years



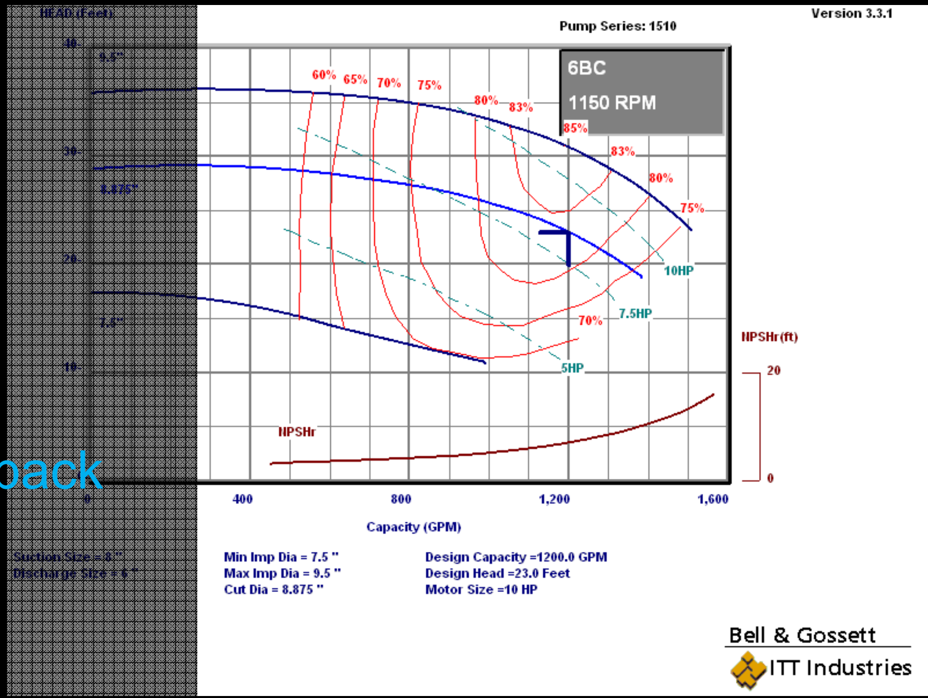
# Option 4 – Replace the Pump

Advantages

- Largest energy savings
- Very persistent

Disadvantages

- Complex implementation
- Most expensive
- Exceeds Owner's simple payback window



# Bottom Lines

| Item | Throttling | Impeller Trim | Speed Reduction | New Pump |
|---|---|---|---|---|
| Savings, kW | 1.44 | 9.44 | 15.12 | 18.46 |
| Annual Savings, kWh | 9,682 | 63,694 | 102,012 | 124,502 |
| Annual Savings | $1,162 | $7,643 | $12,241 | $14,940 |
| Implementation Cost | $1,000 or less | $5,000 or less | $12,850 | $39,557 minimum |
| Simple Payback, Years | .86 or less | .65 or less | 1.05 | 2.65 or more |

Simple measures are good first steps

- Accumulate initial savings while other options are assessed
- Don’t blow the baseline in utility programs by implementing to quickly

# Bottom Lines

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Best Simple Payback May Not be Best Energy Savings

- Implementation cost impacts simple payback

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There May be Critical Issues Beyond Energy Savings and Simple Payback

- Reliability and redundancy can have dollar values associated with them that are as significant or more significant that energy savings

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Best Efficiency Often Equates to Best Selection

- Getting it right the first time is often the best choice
- Getting it right the first time can have first cost benefits

# Bottom Lines

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Achievable Savings may be Constrained by the Owner's financial metrics

- Life cycle cost analysis may swing the financial perspective
- The Owner's economic game drives the economic bottom line

# Bottom Lines

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|---|---|---|---|---|
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*It Depends*

*Jay Santos*

*What's the right choice?*

# Bottom Lines

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For the San Diego Marriott Marquis and Marina condenser water system, a variable speed drive represented the best option for maximizing savings while ensuring guest satisfaction via redundancy in the central plant

# Bottom Lines

In the bigger picture, understanding pumps and piping systems opens the door to a number of benefits

- Optimized selections from the start
  - Better efficiency from the start
  - Lower first costs
  - Fewer ripple effects
- Improved performance and reliability
  - Delivers Non-Energy Benefits (NEBs) that are critical to the Owner's bottom line
- Its *Fun*

# Thank you for participating!

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