Blowers ■ Compressors ■ Vacuum Pumps

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Efficiency Comparisons Between Aeration Blowers

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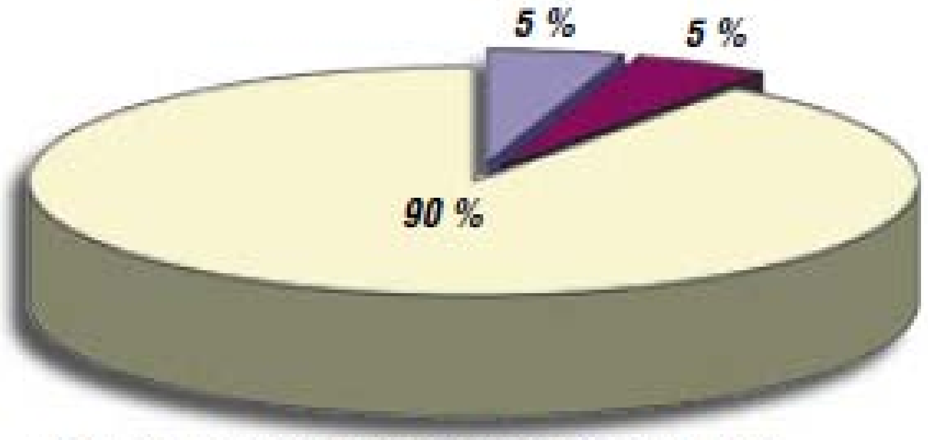
Introduction

- Aeration System
  - Largest Consumer of Power in WWTP
    - 50% to 60% of plant operating cost
  - Life Cycle Costs far exceeds Initial Capital Costs



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Introduction

- Purpose of Presentation
  - Evolution of Blower Technologies
  - Matching the Technology to the Application
  - Right-Sizing of Blowers
  - Accurate Evaluation of Overall Costs

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Traditional Blower Technologies

- Two Lobe Positive Displacement
  - Variable Speed

- Multi-Stage Centrifugal
  - Inlet Throttle Valve or Guide Vanes
  - Variable Speed

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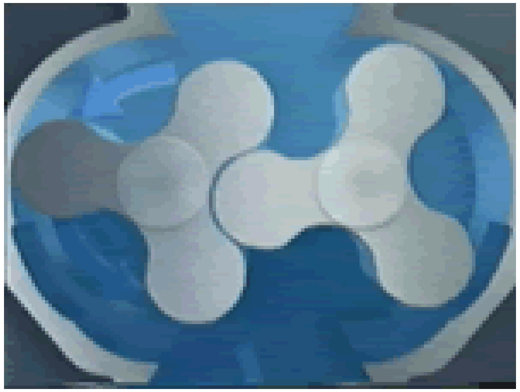
PD Blower Design Principles

- Positive Displacement Blower
  - Constant volume against varying pressure
  - Flow changes by varying speed with VFD
  - Large Turndown (Typically 4:1)
  - Easily adapts to changes in pressure & temperature
  - Widely used / Low initial cost



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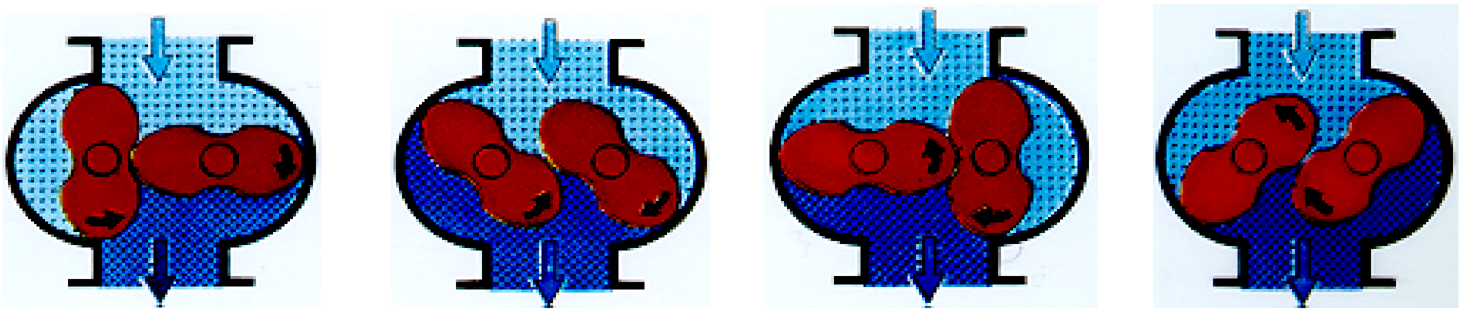
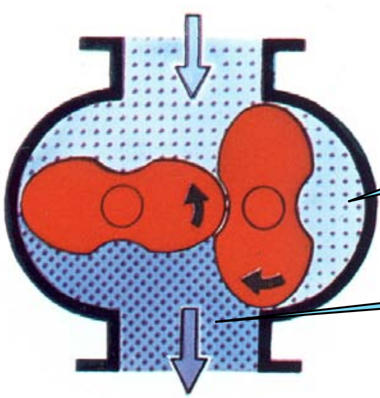
PD Blower Evolution

- Two-Lobe to Three-Lobe Technology
  - Pulsation Cancellation
    - Less wear and tear on components and piping
  - Single Forging of Shaft and Impeller
    - Stronger, More Stable at Higher Speeds
  - More Effective Noise Reduction
    - Quieter packages
  - Upgraded Seals (Piston Ring)
    - Longer maintenance intervals on internals

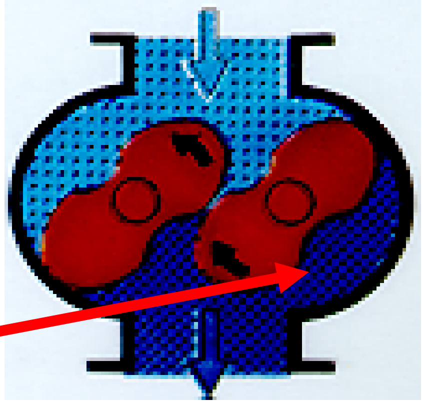
2-Lobe Conveying Cycle





Atmospheric pressure

System pressure



Abrupt pressure equalization causes noise and shocks (pulsations) 4 times per revolution.

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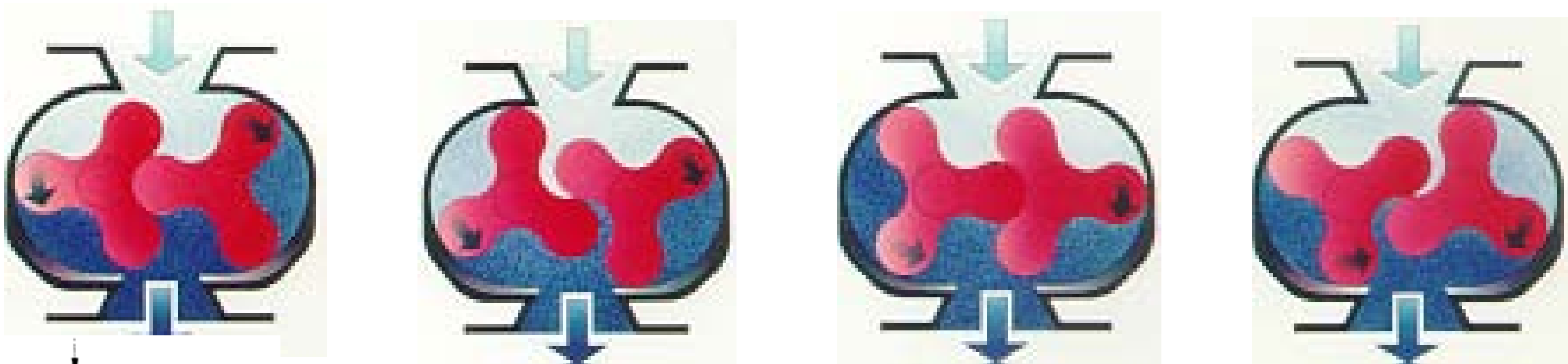
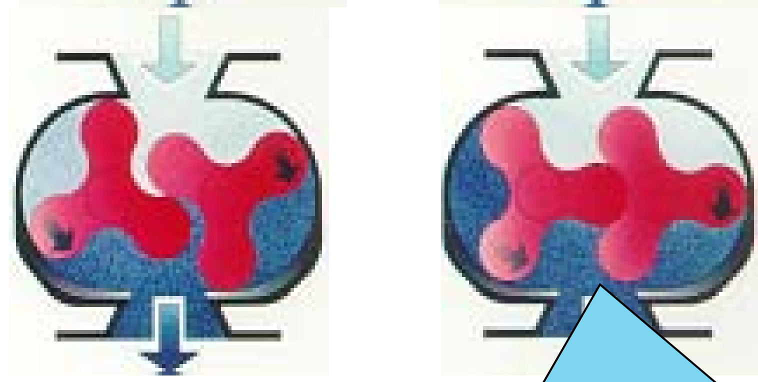
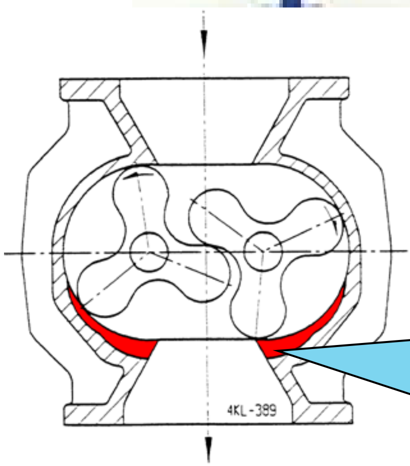
Three-Lobe Conveying Cycle





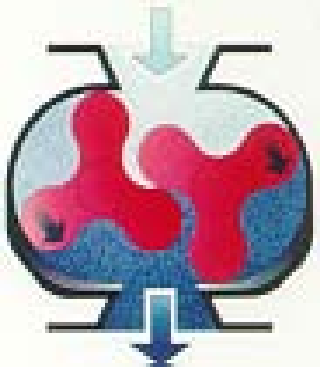


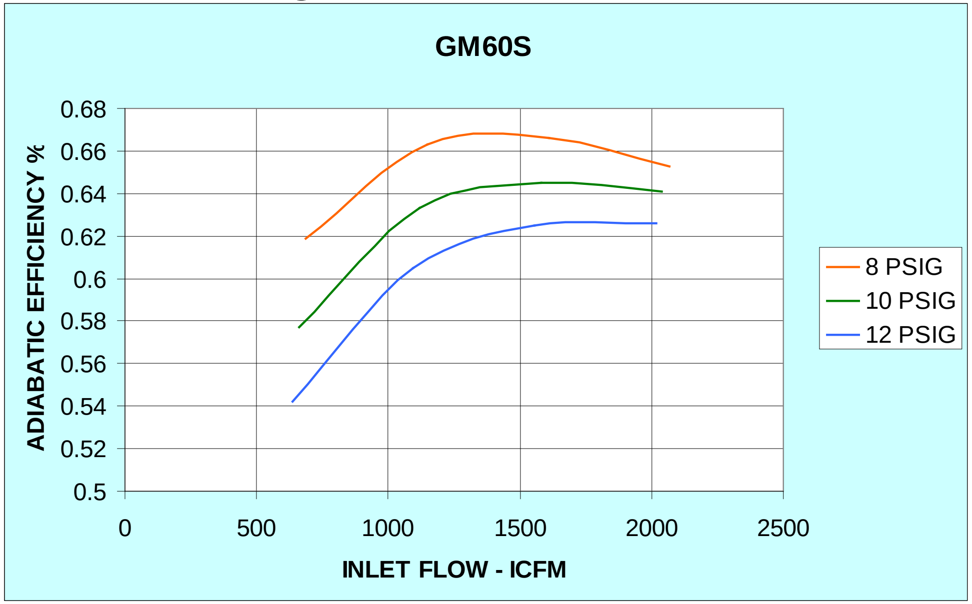
Integrally cast return ports gradually pressurize casing

Squeeze pulse is 180° out of phase with Pressure pulse.

Limitations of PD Blowers

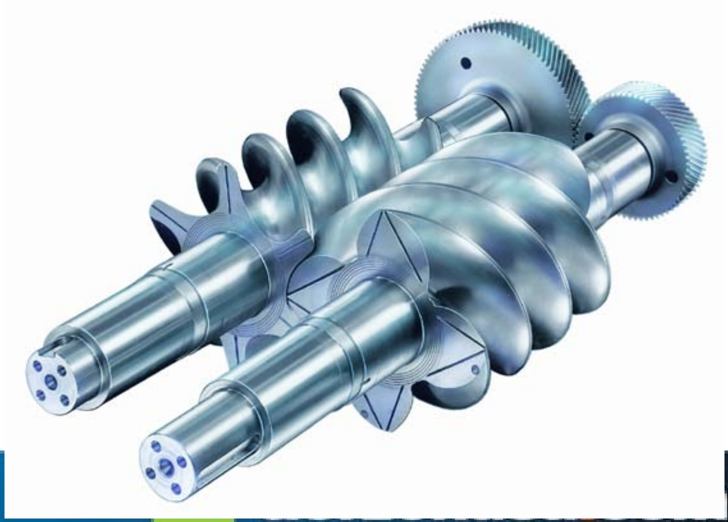
- Efficiency
  - Slip between Rotors
  - Less efficient at Lower Flows
  - Less efficient at Higher Pressure





Compressor Design Principles

- Positive Displacement Compressor (VML)
  - Used since the 1940's (Deep Cell Aeration)
  - Rotors mesh, compressing air inside housing
  - Flow changes by varying speed (VFD)
  - Best around 20 to 30 psig
  - Higher capital cost (2X PD blower)



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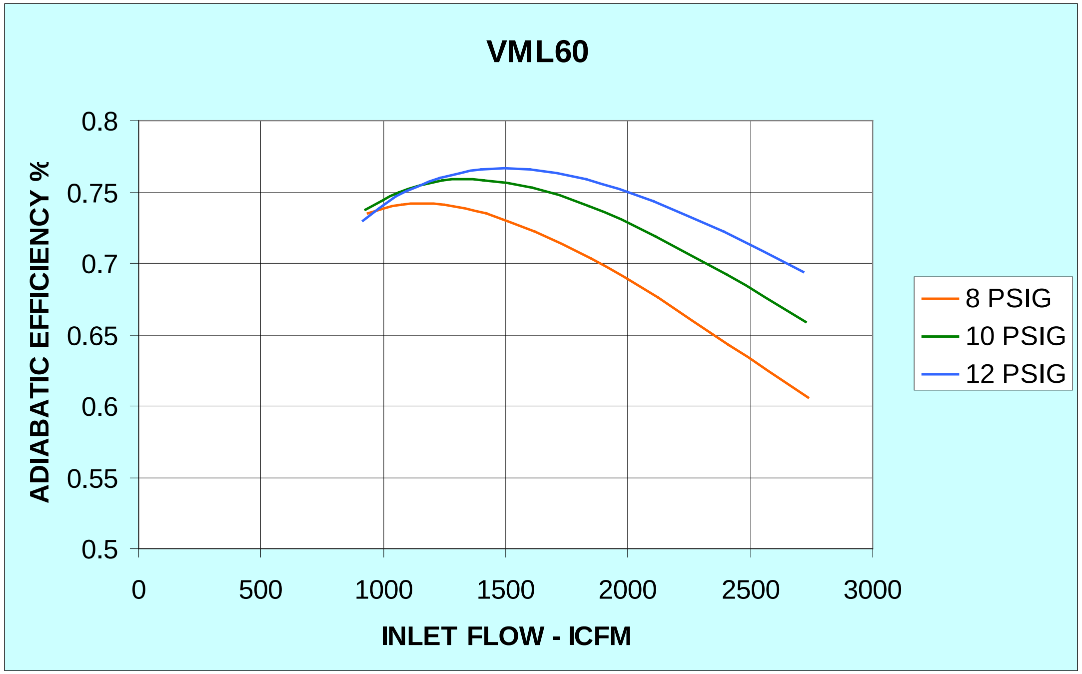
Limits of Screw Compressors

- Efficiency
  - Less efficient at Lower Pressures



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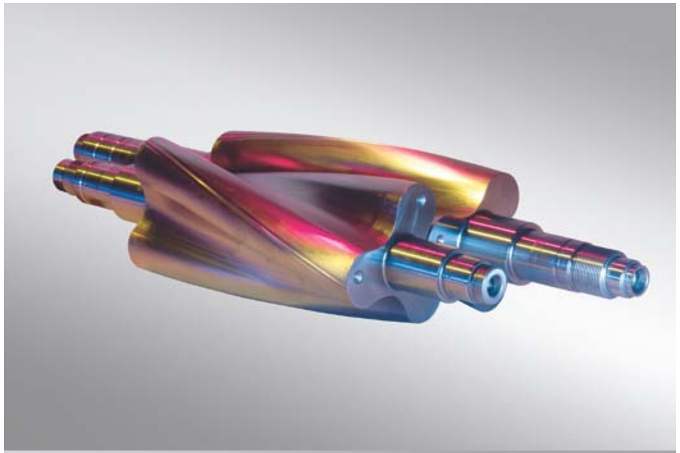
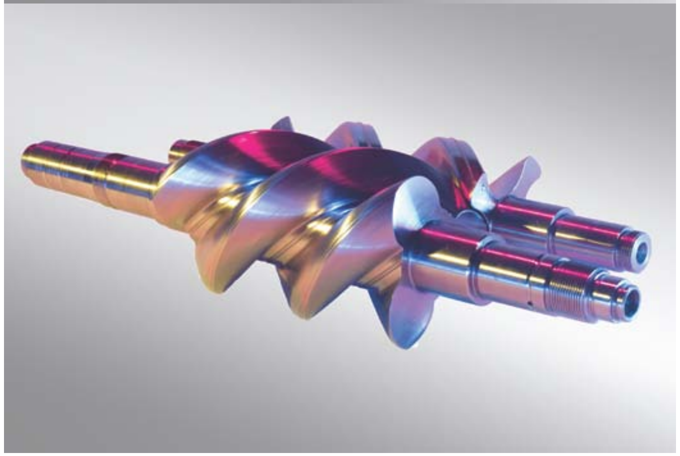
Adaptation to WWTP Use

- Low Pressure:
  - 3 – 7 PSIG
  - Twisted Lobes



- High Pressure:
  - 7 – 15 PSIG
  - Screw Compresso



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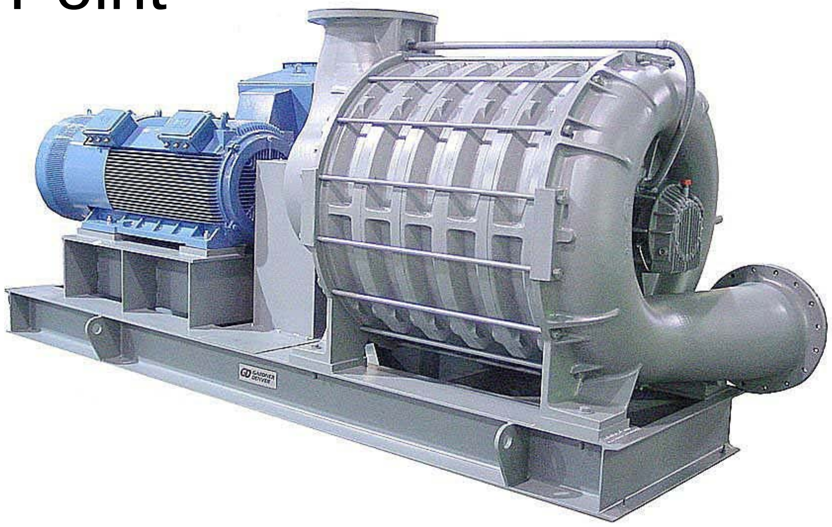
Centrifugal Design Principles

- Multi-Stage Blower
  - Widely used technology
  - High Flow, Small Footprint
  - High Efficiency at Design Point

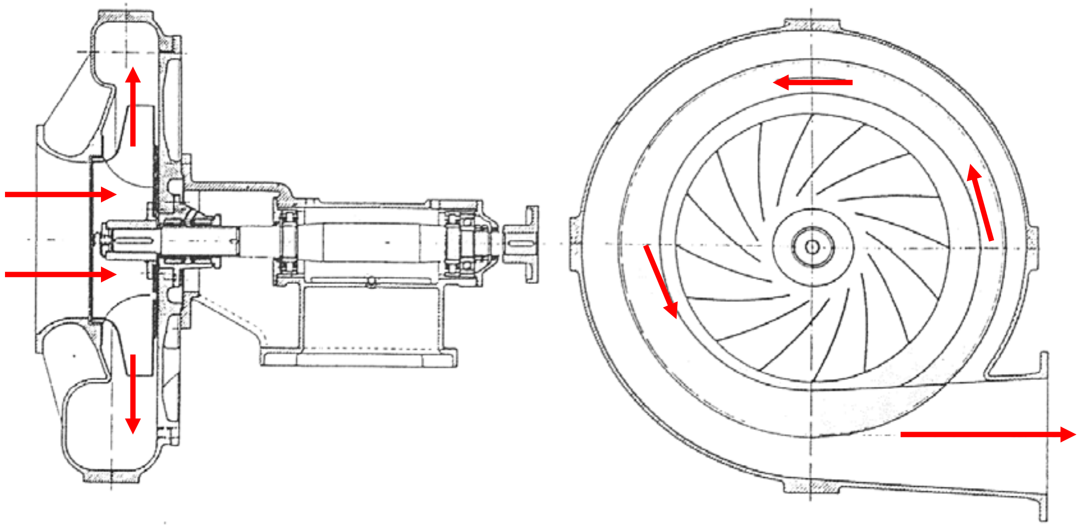
DRESSER Roots

GARDNER DENVER



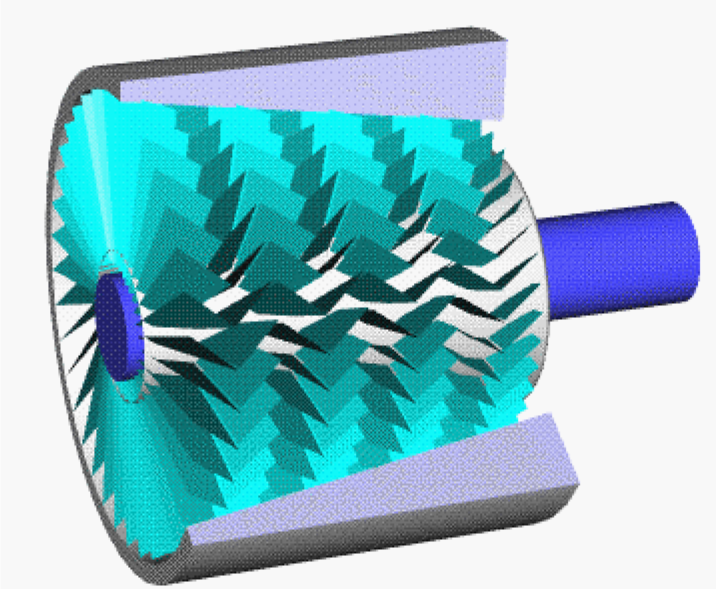
Centrifugal Design Principles

- Centrifugal Blowers (Dynamic Compression)
  - Kinetic Energy to Potential Energy



Centrifugal Evolution

- Multi-Stage
  - Repeats the Compression Process in Series
  - Relatively low speed
    - 3600 RPM



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Centrifugal Evolution

- Turbo Blower – Gear Drive
  - High efficiency, even at turndown
  - Bullgear raises Impeller Speed (Single Stage)
  - Inlet guide vanes and discharge diffuser vanes
  - Complex control system
  - High capital cost
  - More Cost Effective >400HP

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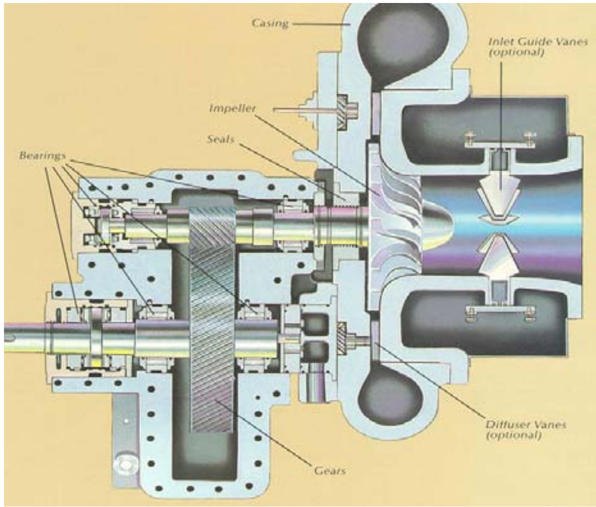
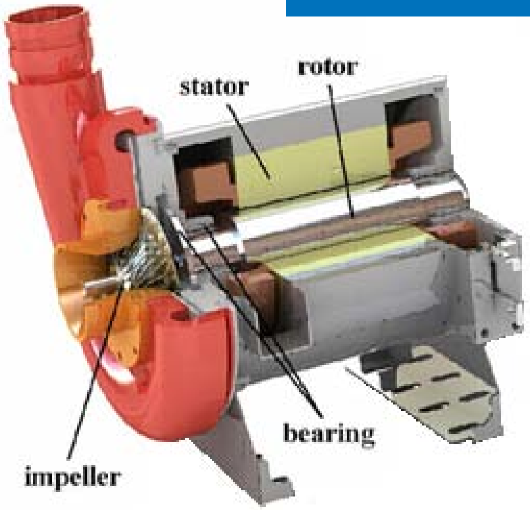


Centrifugal Evolution

- High Speed Turbo Blower
  - Newest in WWTP market (<5 years)
  - Air-Foil Bearings, Permanent Magnet Motor
  - Integral VFD and Control System
  - More Affordable than Gear Drive
  - Wide Range of Sizes
  - Life Cycle Cost Payback



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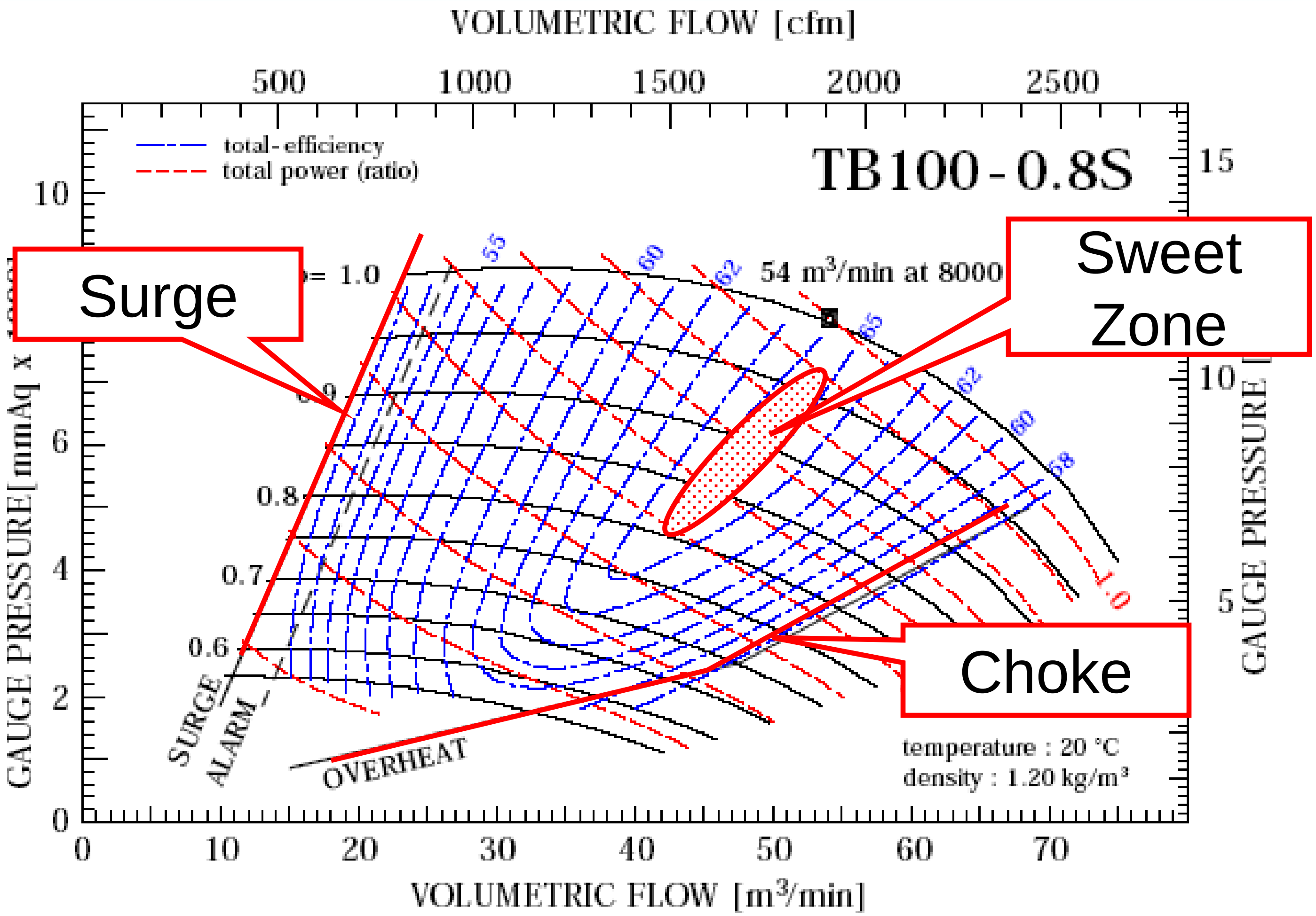
Centrifugal Design Principles

- Dynamic Compression
  - Sweet Zone of Efficiency
- Must Reside on Performance Map
  - Flow too Low or Pressure Too High: Surge
  - Flow too High or Pressure Too Low: Choke
  - Performance Varies with Air Density
    - Summer (High Loads, Low Air Density)
    - Winter (Low Loads, High Air Density)

Centrifugal Design Principles



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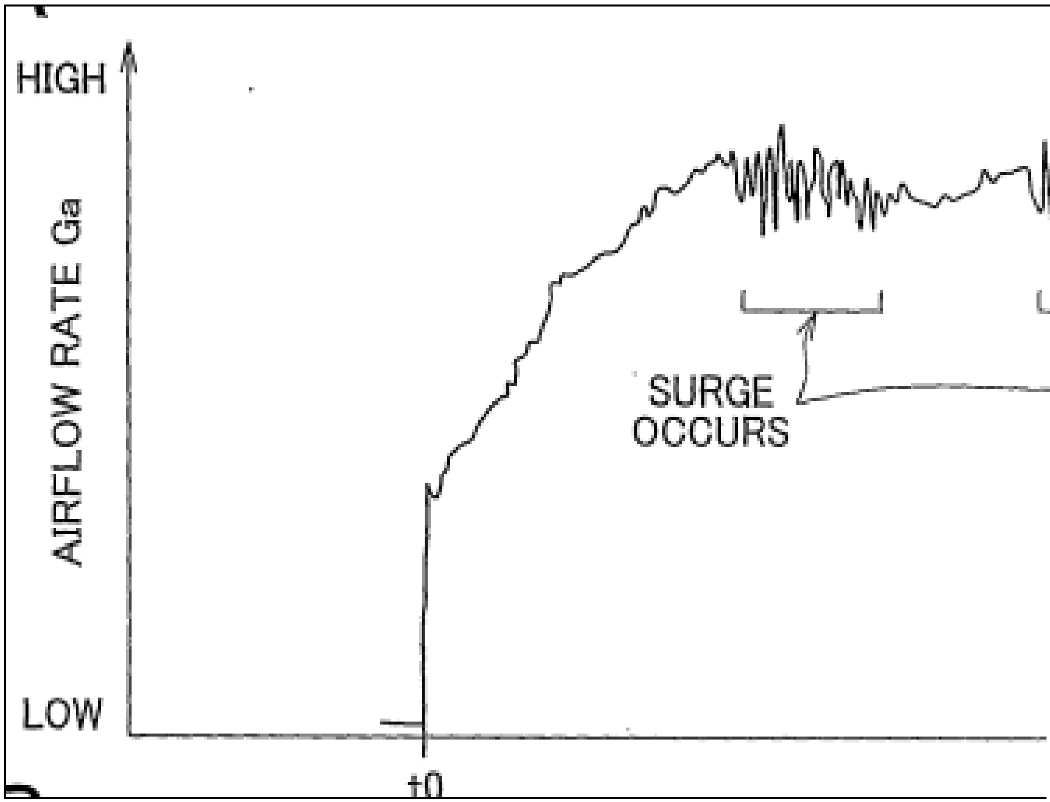
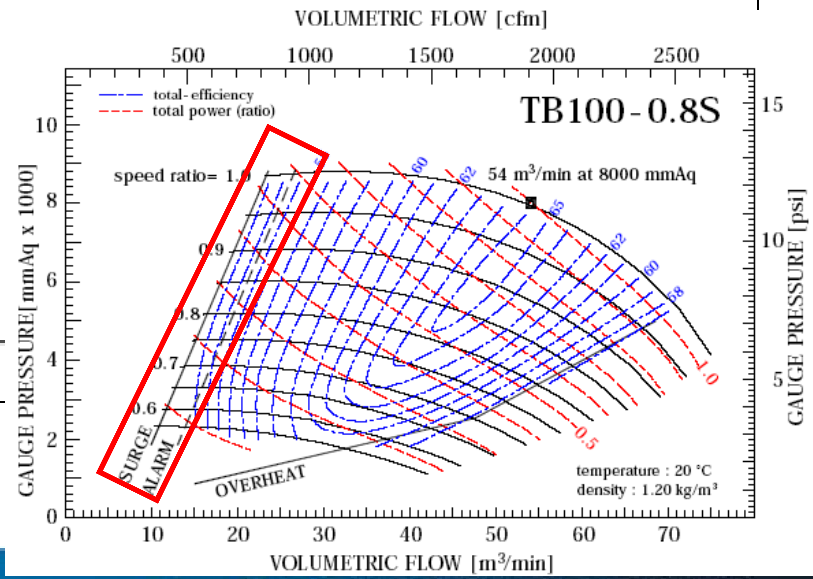
What is Surge?





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Centrifugal Design Limitations

- Control Is Essential
  - Protect the Blower
  - Satisfy System Air Requirements

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Centrifugal Blower Control

- Multi-Stage:
  - Throttling Valve / Inlet Guide Vanes
  - Speed Control (VFD)
- Gear Drive Turbo:
  - Inlet and Discharge Vanes, Speed Control
  - Control System (PLC)
- High Speed Turbo:
  - Motor Control (Speed, Current)
  - Control System (PLC or CPU)

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What Technology to Choose?

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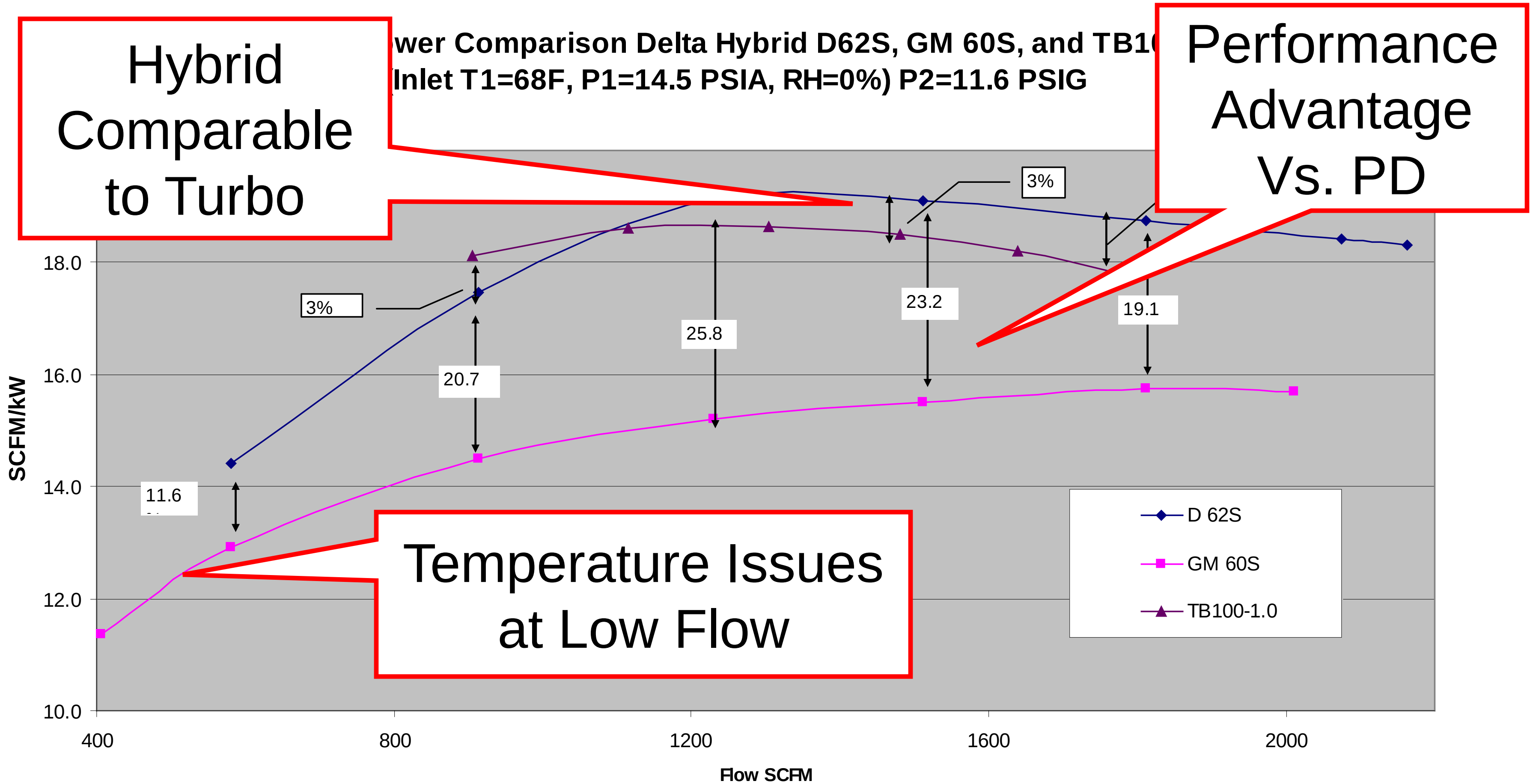
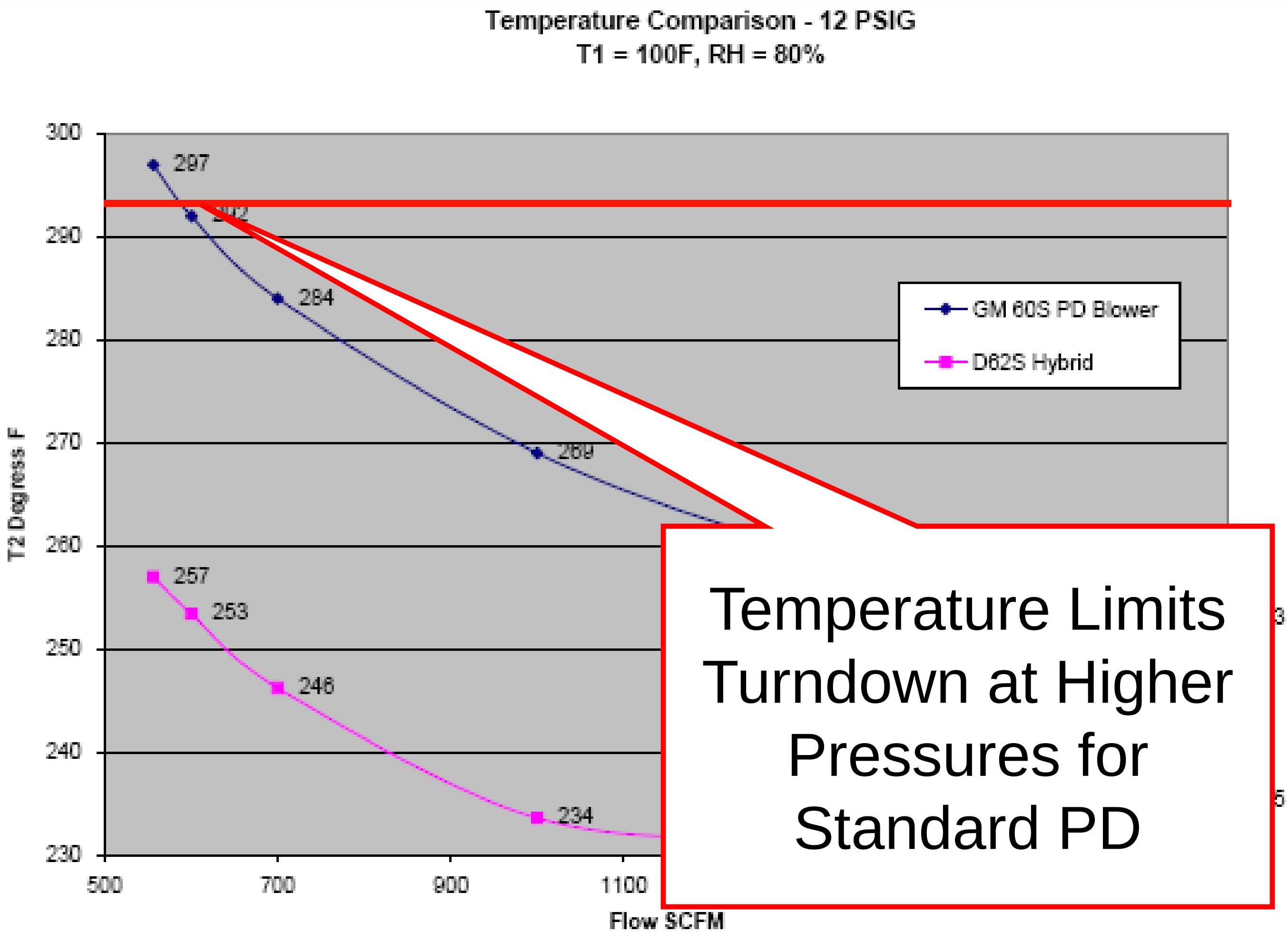
Start With the System

- System Flow Requirements
  - Minimum, Maximum, Average
  - Factor in Diurnal Minimum
- Pressure (Constant or Varied, and How Much)
- Site Conditions (Elevation, Ambient Range)
- Control Requirements
  - On/Off, VFD, Combination

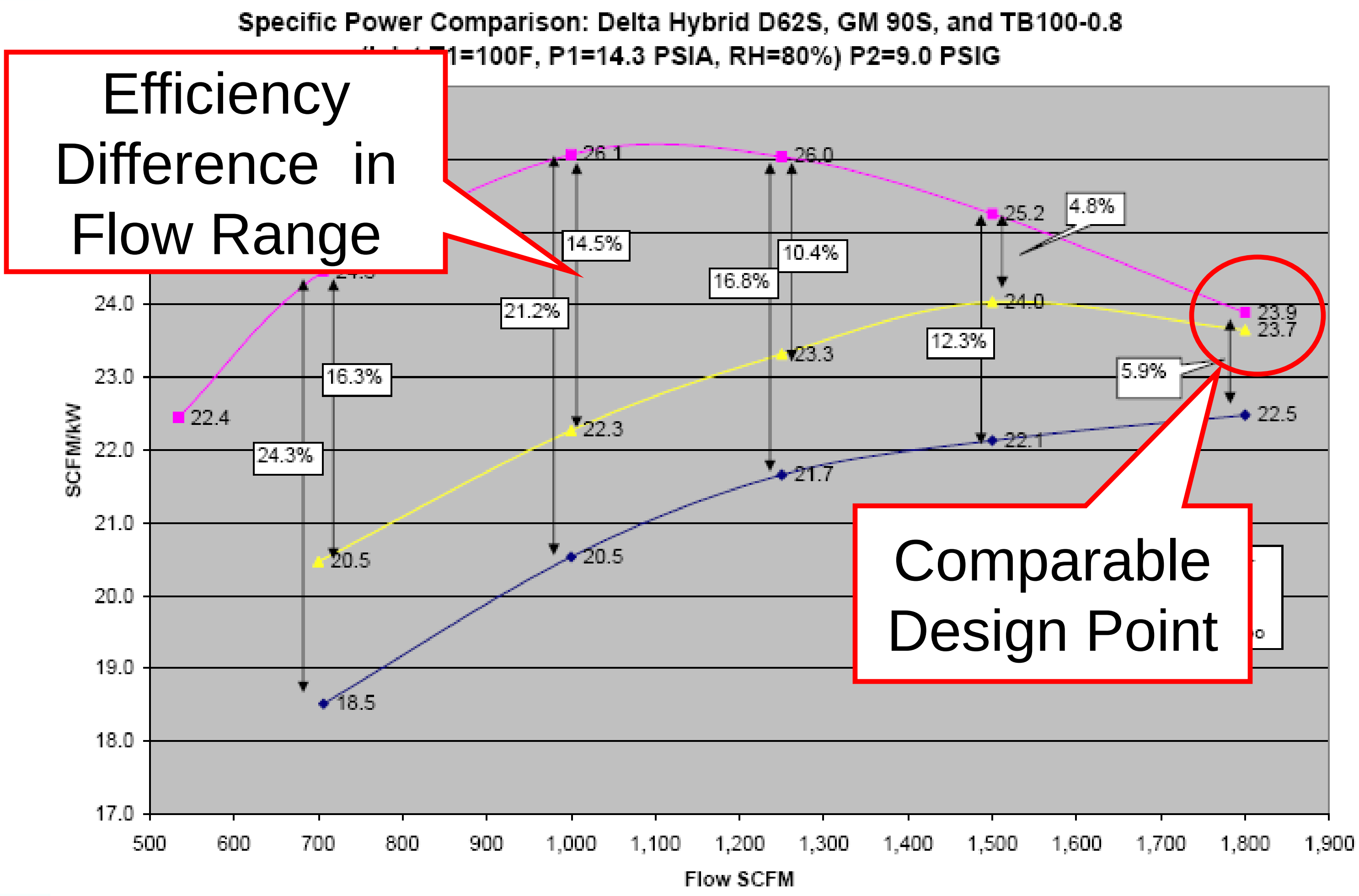
Performance Comparison



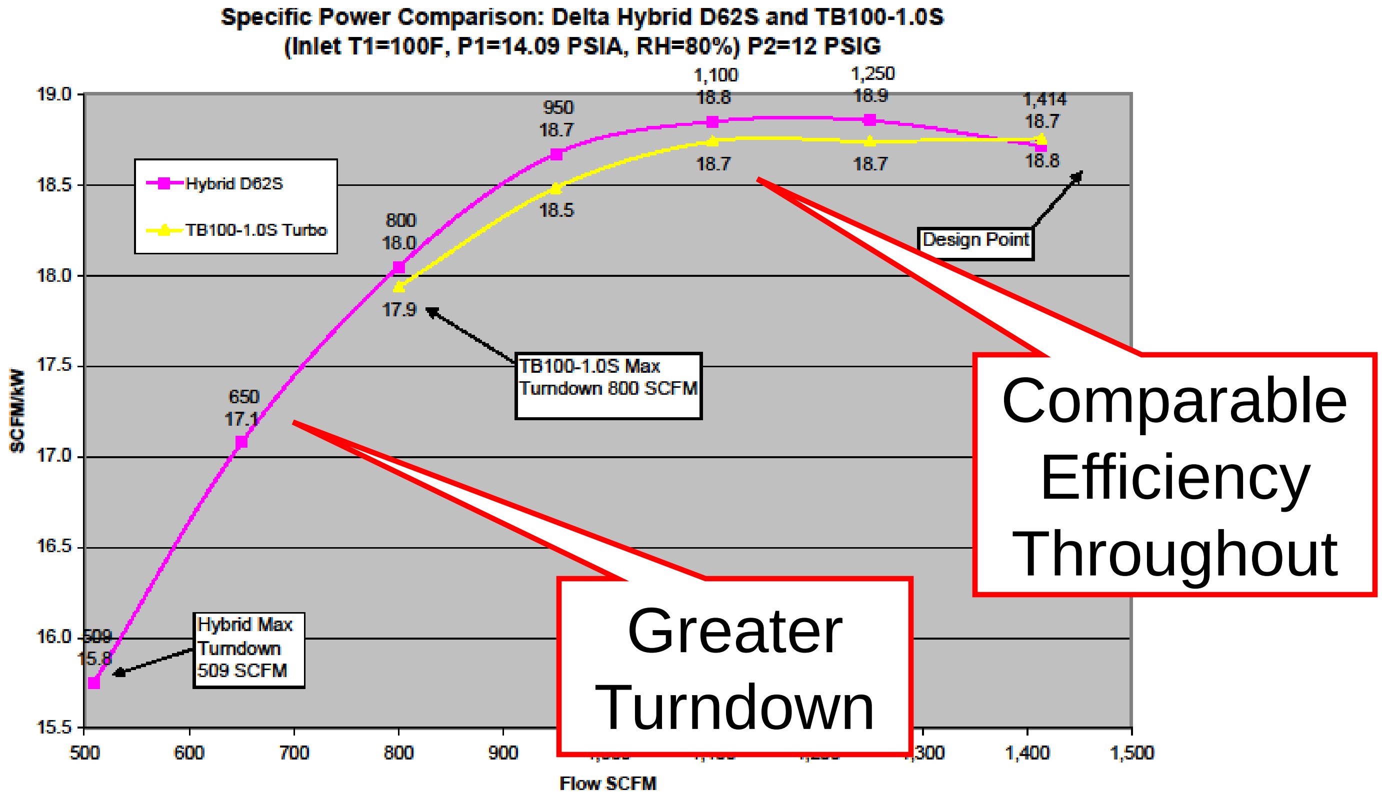
Temperature Concerns



Performance Comparison



Performance Comparison



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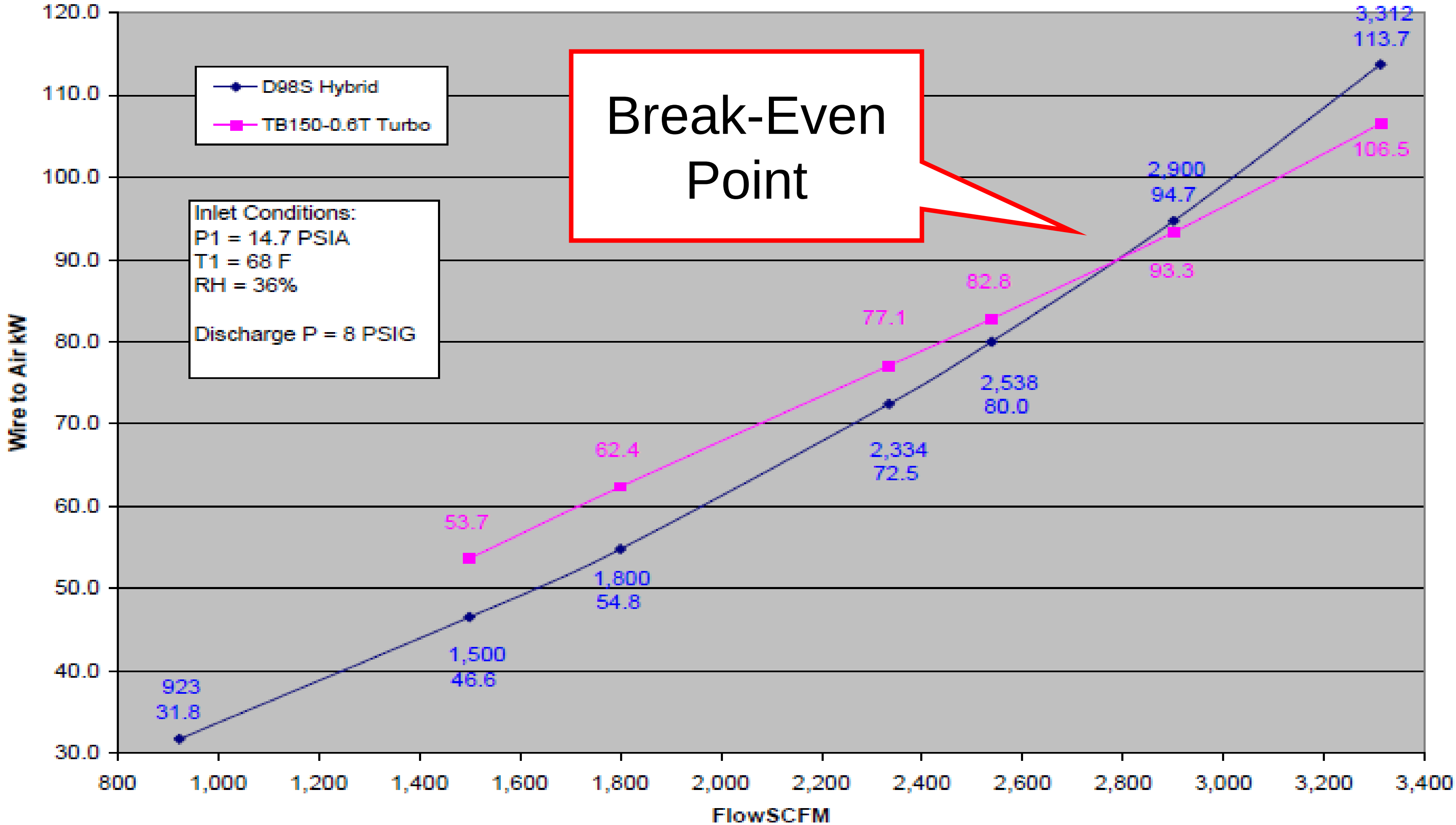
Performance Comparison



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Sensitivity Analysis

Sample Power Comparison - Cheshire CT

System		Weight	TM150-0.6T		D98S	
ICFM	PSIG	% Time	W-T-P kW	KW-Hours	W-T-P kW	KW-Hours
3312	8	5%	106.5	46647	113.7	49801
2900	8	5%	93.3	40865	94.7	41479
2538	8	10%	82.8	72533	80.0	70080
2334	8	25%	77.1	168849	72.5	158775
1800	8	25%	62.4	136656	54.8	120012
1500	8	20%	53.7	94082	46.6	81643
923	8	10%	53.7	47041	31.8	27857
		100%		606674		549646

Cost per kWH:	$0.1426	$0.1426
Annual Power Cost:	**$86,511.68**	**$78,379.55**

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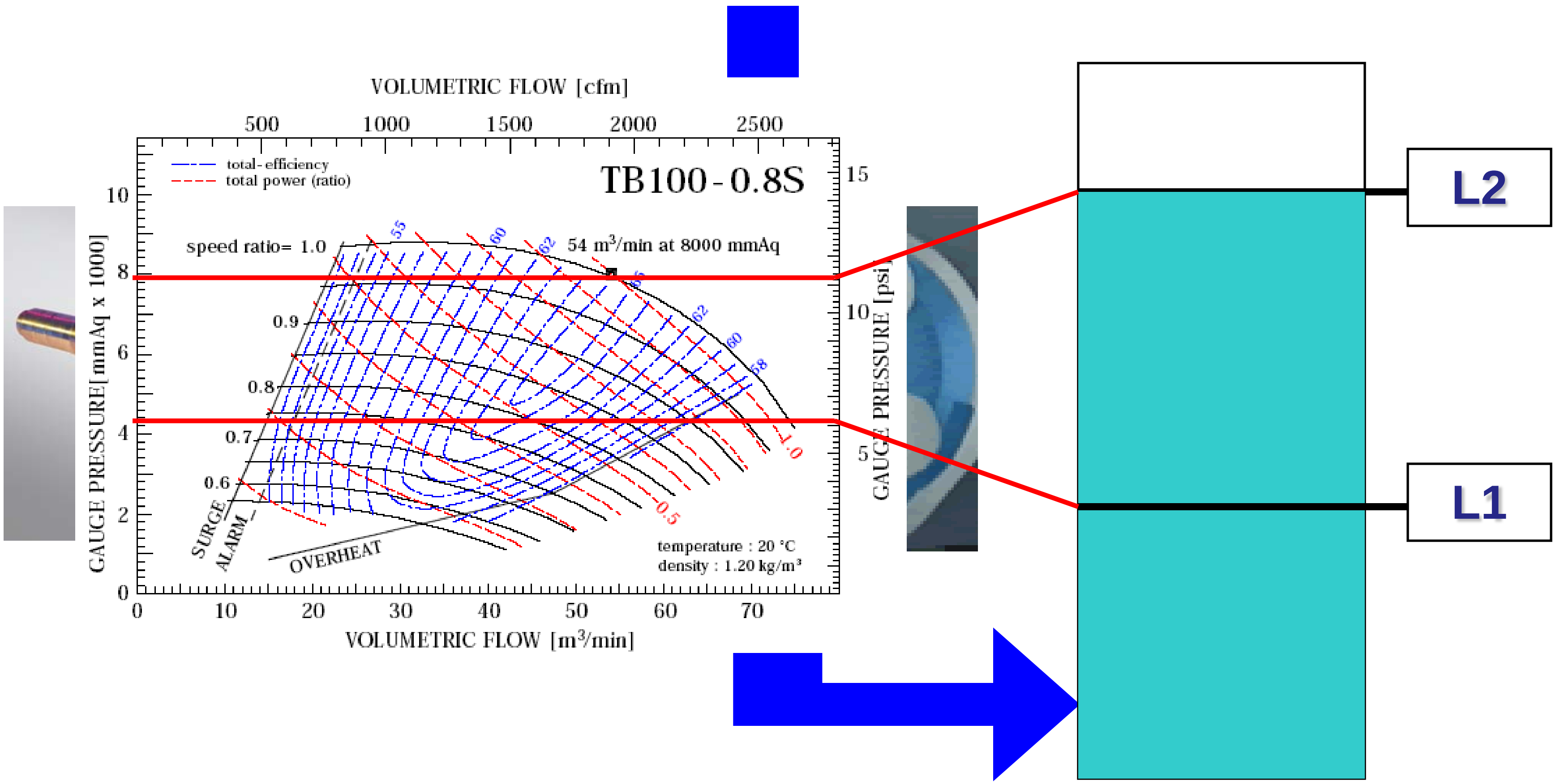
Pressure Variation



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Site Conditions

31% Variation in O_2 Content

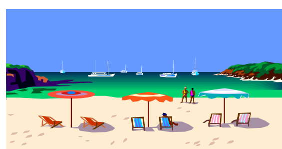
Denver, CO

12.2 psia (0.84 bar abs)

+ 115ºF (46ºC)
+ 55ºF (13ºC)
- 17ºF (-27ºC)

Miami, FL

14.7 psia (1.013 bar abs)



+ 98ºF (36ºC)
+ 76ºF (24ºC)
+ 30ºF (-1ºC)

14% Variation in O_2 Content

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Why Site Conditions Matter

- Density affects compression ratio
  - Higher Elevations Limit PD
- Percent O_2 impacts aeration requirements
  - ICFM vs. SCFM
- Maximum flow on Hottest Day
  - Perfect Storm Design
- Minimum flow on Coldest Night
  - More Likely

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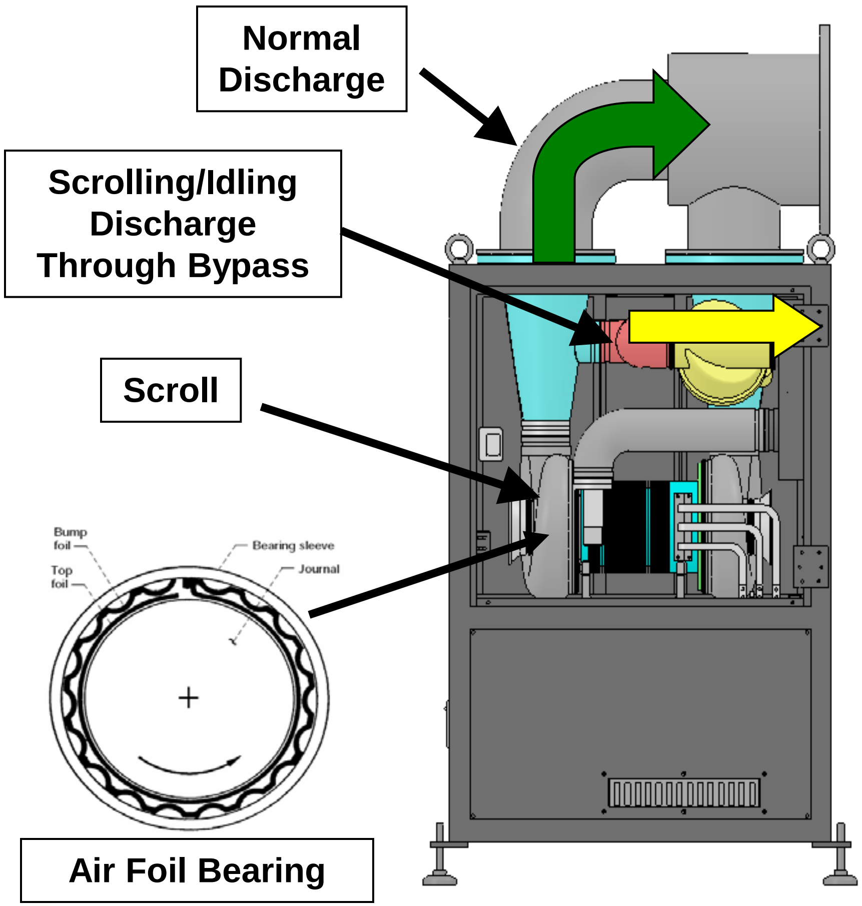
System Control Requirements

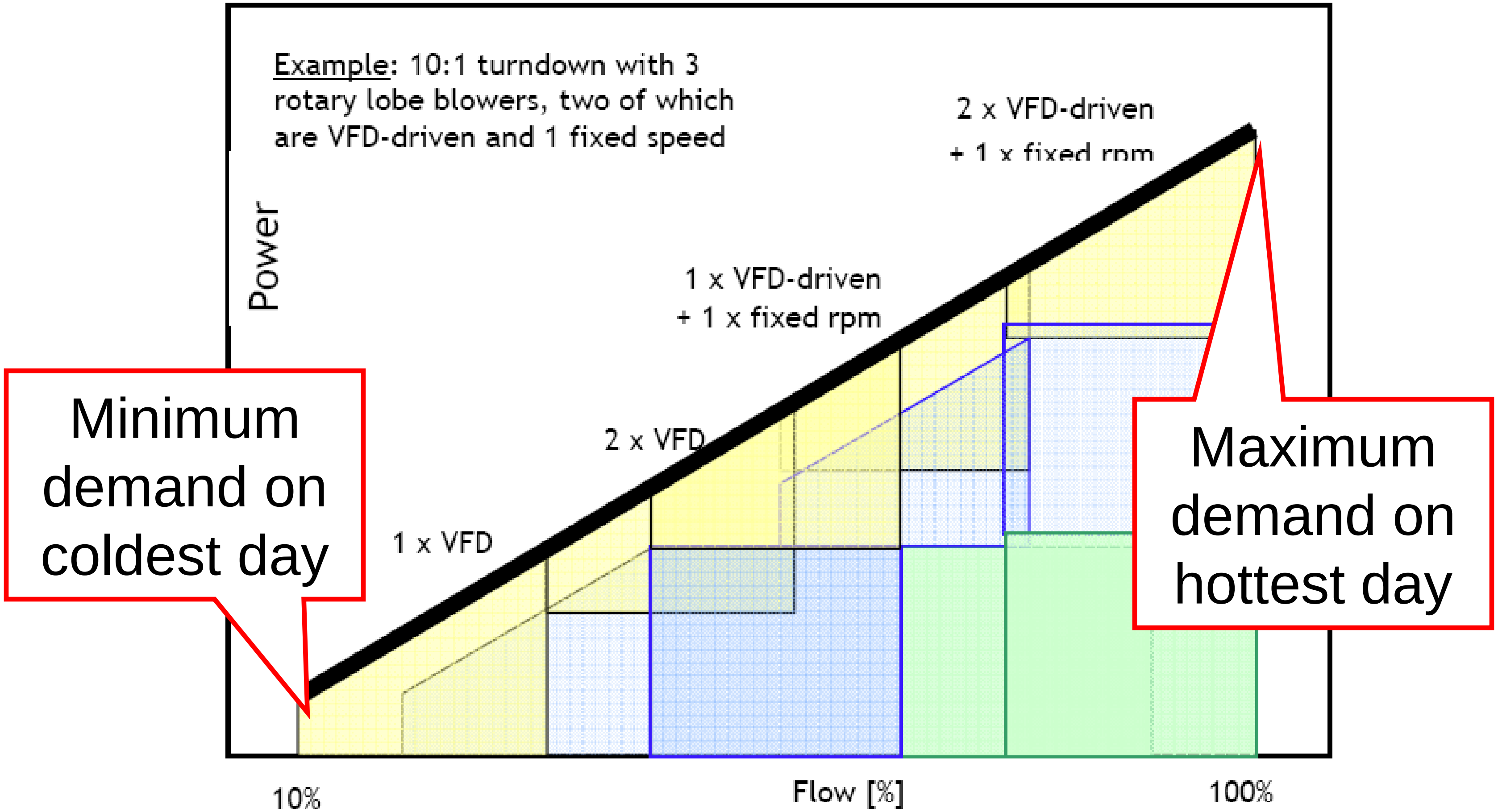
- On/Off Cycling
  - PD Blower / LP Screw / Multi-Stage - Good
  - NEMA Motor (4-6 starts/hour)
    - VFD Extends # of Starts
  - Turbo – Challenged if cannot run unloaded
    - High Frequency VFD may limit daily starts
    - Airfoil Bearings limited to 20,000 starts
      - Or <20,000 (Depending on Design)

Idling/Scrolling Function



- Bypass Valve Opens
- RPM Drops to ~10,000
  - Sufficient to maintain “loft” on Bearings
  - Minimal Power Draw (Avg 2%: 2 – 5 kW)
- Avoids Bearing Wear
- Avoids Start/Stop Cycles
- Useful in SBR/MBR Systems

Right-Sizing



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Right Sizing Options

- One 100% Unit/System with common spare.
  - Base Load, Upper Flow Range
- Two 50% Units with Common spare.
  - Greater Net Turndown
  - More Machinery
- Base Load Machine, Swing Machine
  - Mixed Technology
  - Optimize Efficiency Throughout Range

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Life Cycle Costs

- Energy Usage
  - Anticipated Operating Points
  - Assign Time and Conditions
  - Require Manufacturer to Provide TOTAL kW
    - Include ALL Mechanical & Electrical Losses
    - ASME PTC-13

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Life Cycle Costs

- Installation
  - Indoor or Outdoor
  - Integral VFD or Separate
  - Available Footprint

Life Cycle Costs

- Maintenance:
  - PD (Blower, Compressor):
    - Annual Oil Change
    - Belt Change (12-18 months)
    - Air Filters as needed
    - Bearings/Seals (15-20 Years)
  - Turbo:
    - Air Filters: Prefilter (1-2 Mos), Fine Filter (6 Mos)
    - Impeller Cleaning (3 Years)
    - Electronics (capacitors) (5 Years)
    - PM Motor (10 Years)

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Your Final Decision

- Accurate Energy Cost Evaluation
- Life Cycle Costs
- Proven Technology
- Serviceability
- Accountability of the Manufacturer

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Thank you for your Attention

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