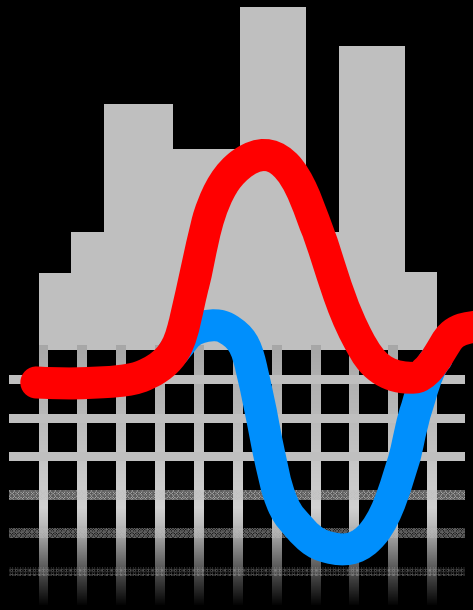

Facility Dynamics
ENGINEERING

Introduction to the Controlled Systems

Pumps and Fans (Supplemental)

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What We Will Cover in This Module

- Basic operating principles for centrifugal machines
- How pumps and fans can be optimized
- How pumps and fans interact when they are in parallel

How Centrifugal Machines Work

If You Understand One, You Probably Understand them All

Pump Power; a Direct Function of Flow and Head

$$bhp = \left(\frac{gpm \times head}{3{,}960 \times \eta_{pump}} \right)$$

Where:

bhp = Brake horse power into the pump drive shaft

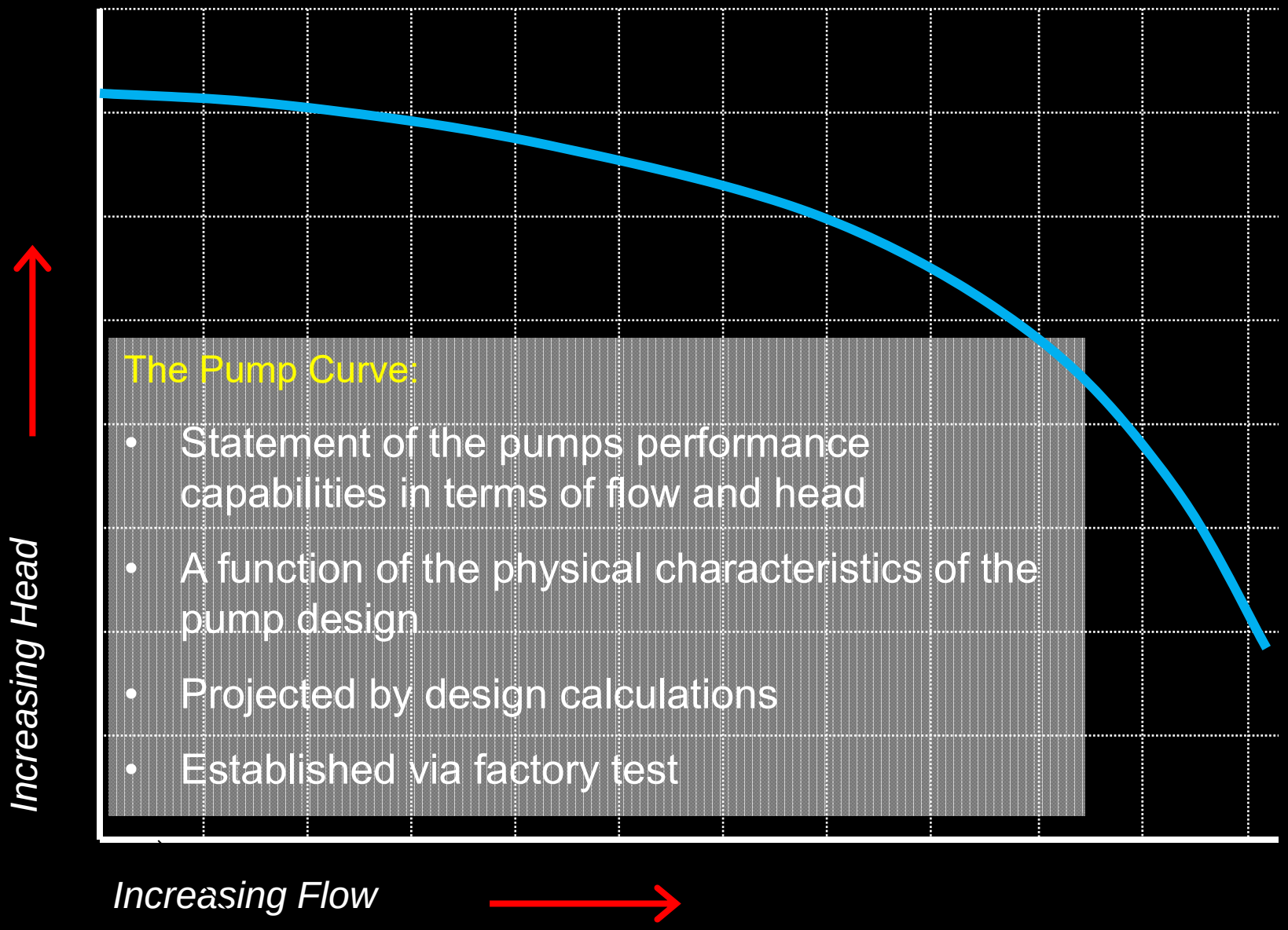
gpm = Flow rate in gallons per minute

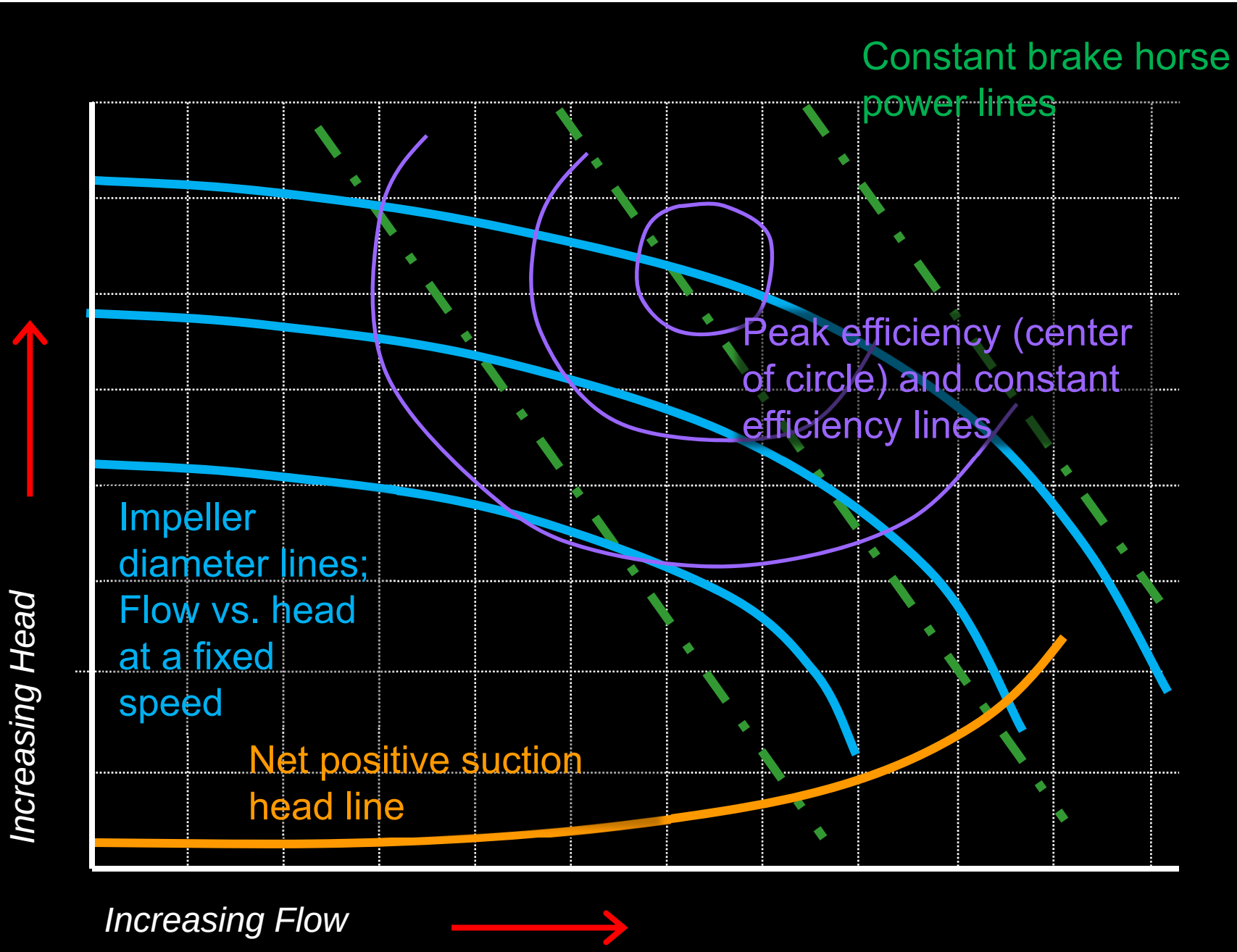
$head$ = Pump head in feet water column

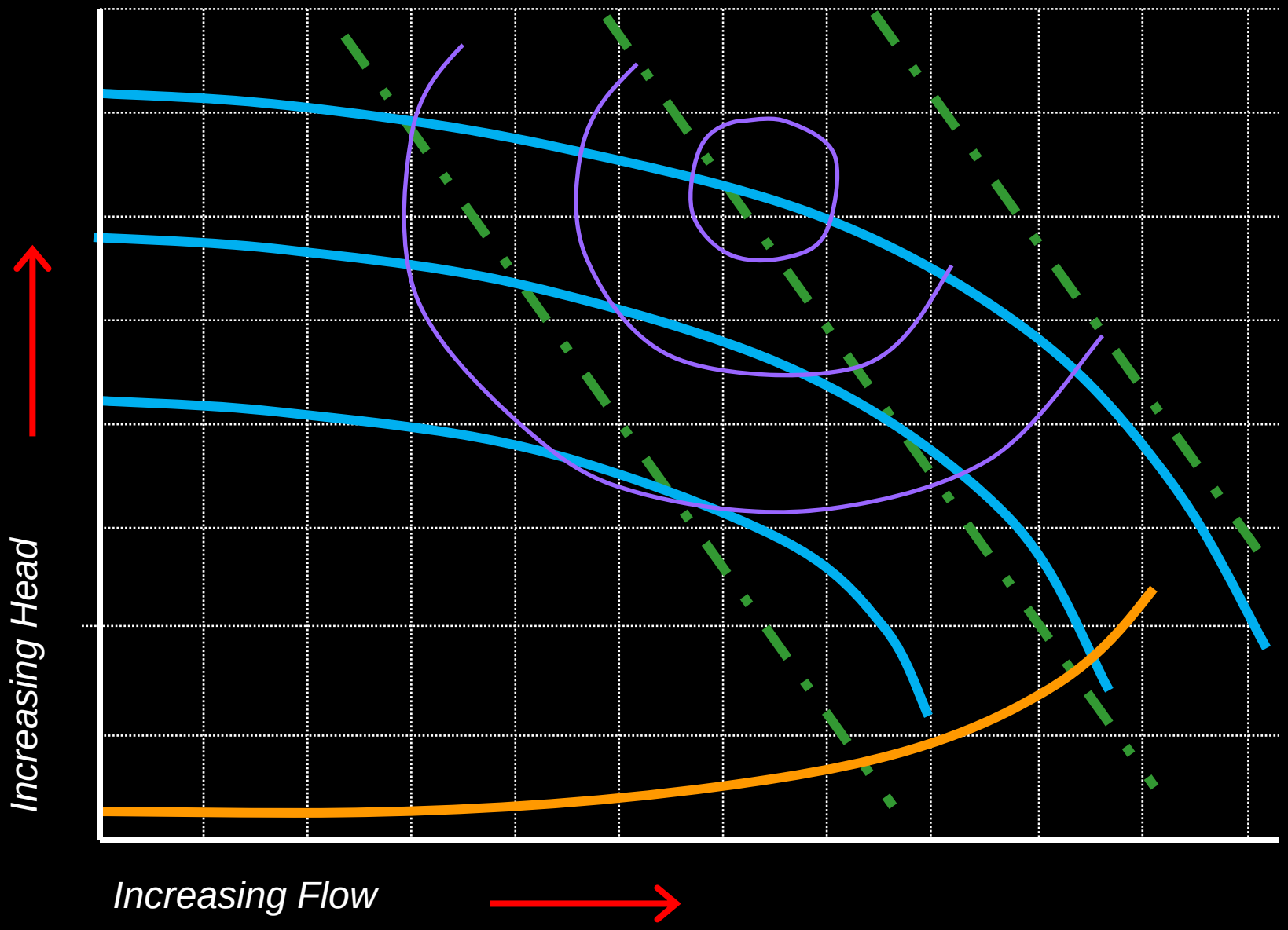
3,960 = A units conversion constant

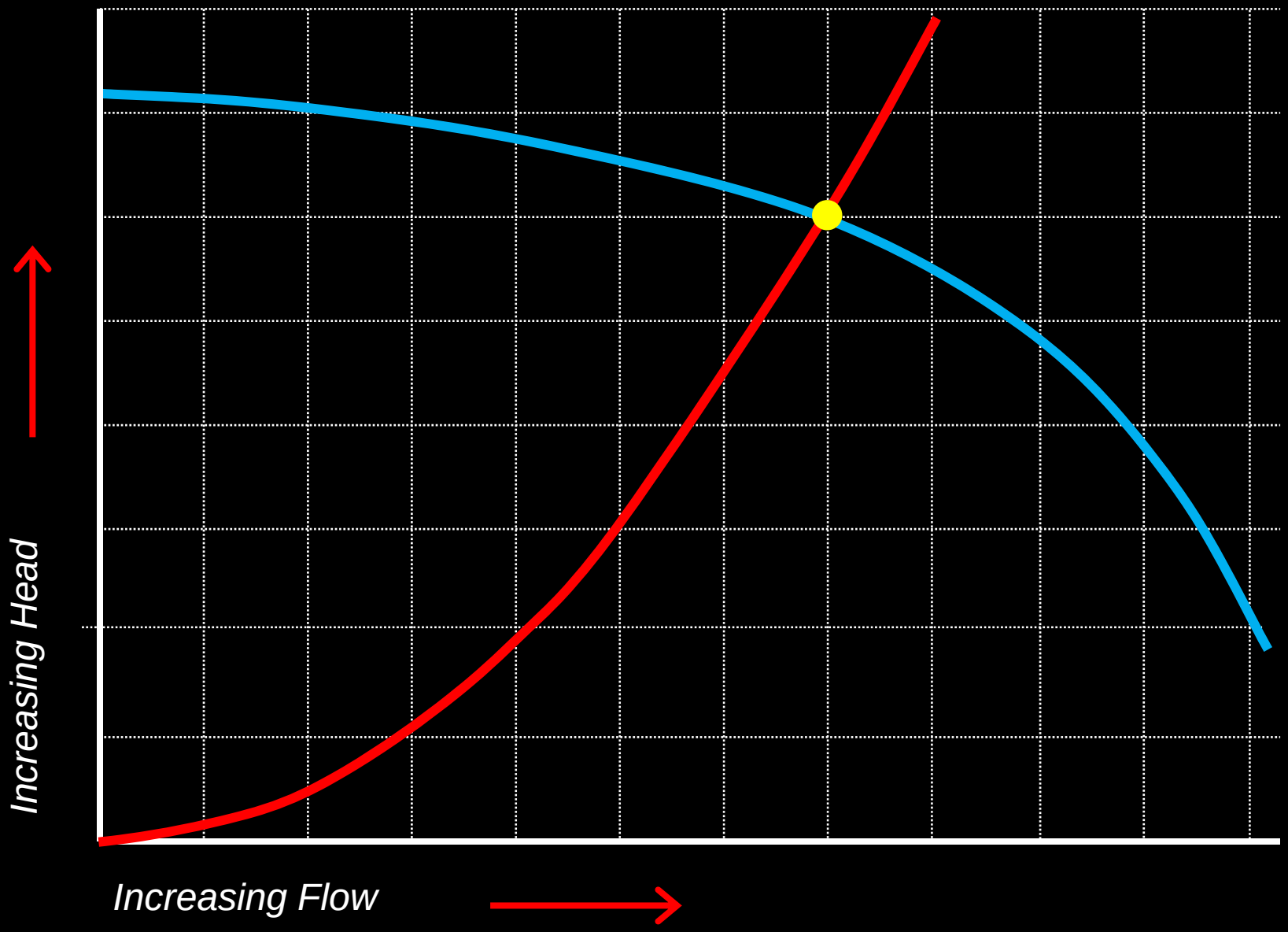
η_{pump} = Pump efficiency; .4 - .65 for small pumps,
.75 - .85 for large pumps

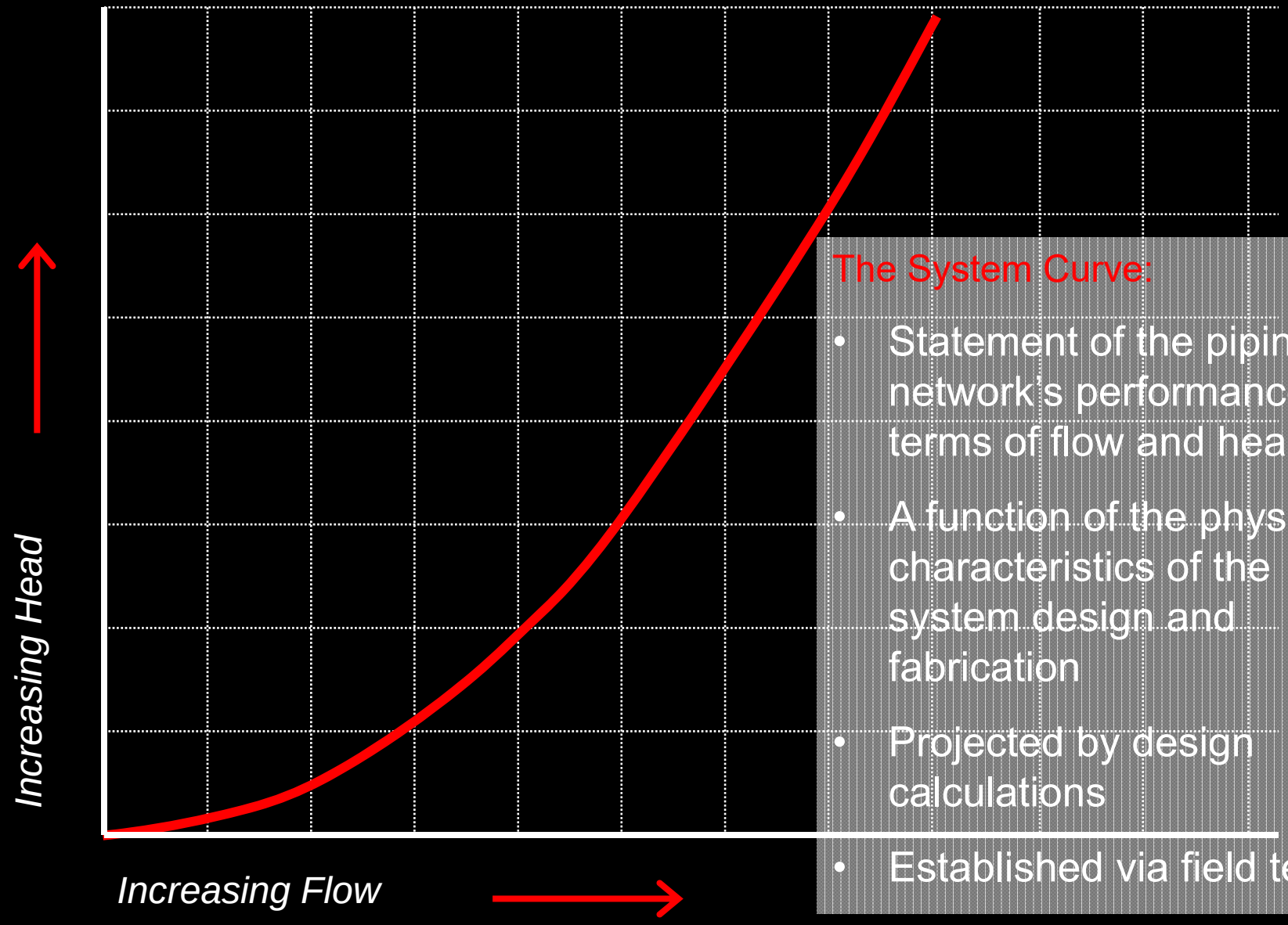
Divide by motor efficiency and multiply by .746 kW per horse power to get killoWatts


Increasing Head
Increasing Flow
The Pump Curve:
• Statement of the pumps performance capabilities in terms of flow and head
• A function of the physical characteristics of the pump design
• Projected by design calculations
• Established via factory test


Constant brake horse power lines
Peak efficiency (center of circle) and constant efficiency lines
Impeller diameter lines; Flow vs. head at a fixed speed
Net positive suction head line
Increasing Head
Increasing Flow

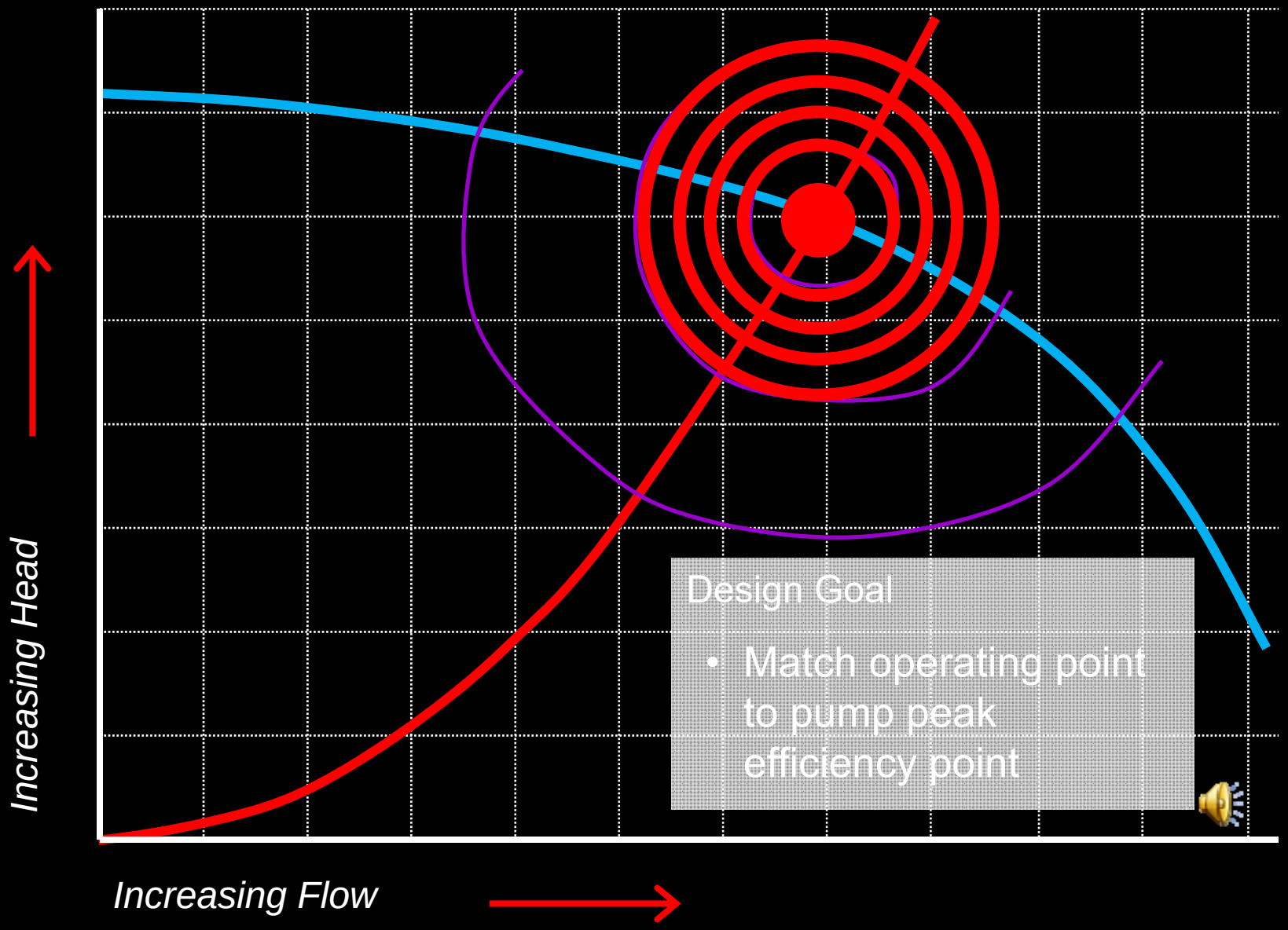

Increasing Head
Increasing Flow


Increasing Head
Increasing Flow

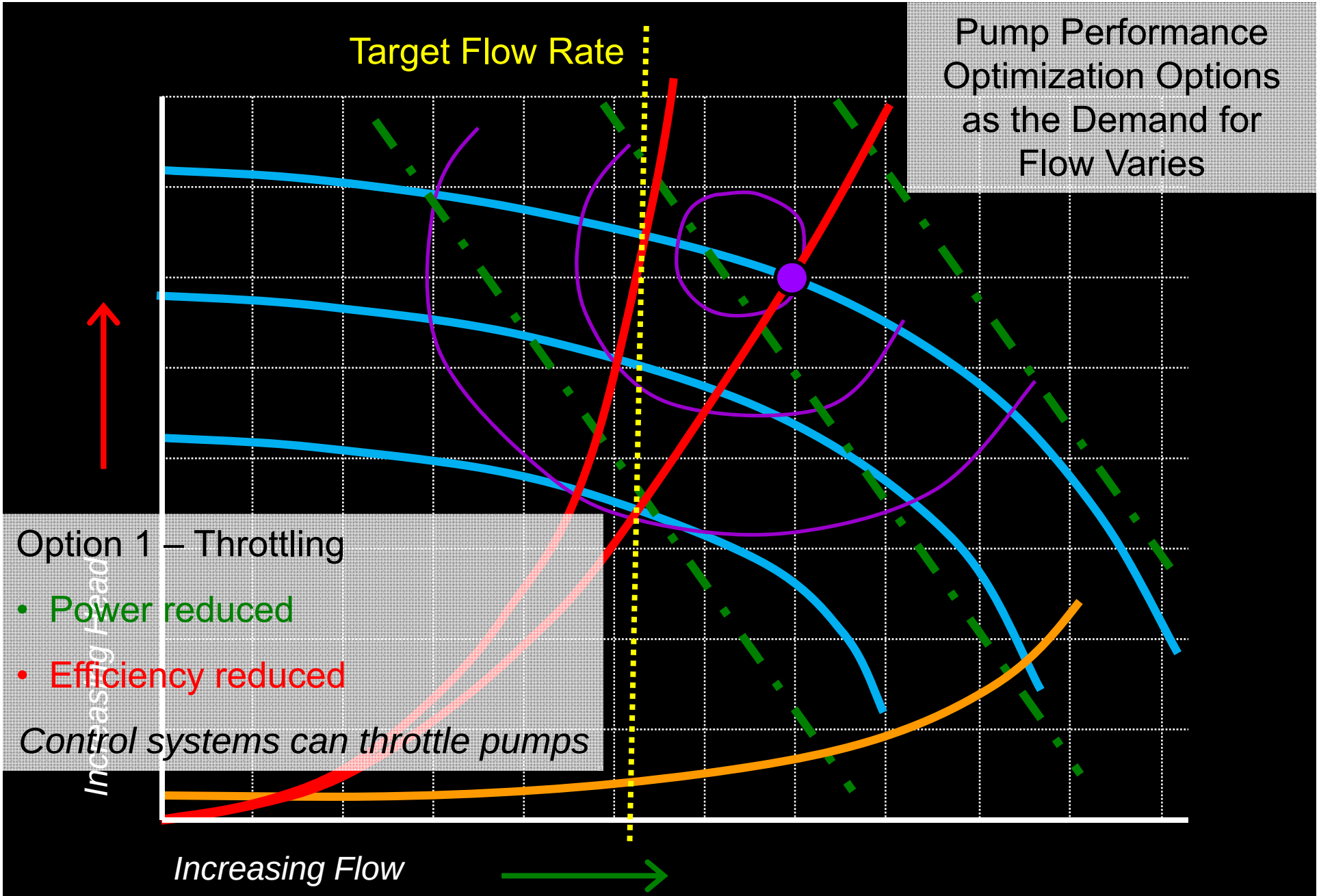


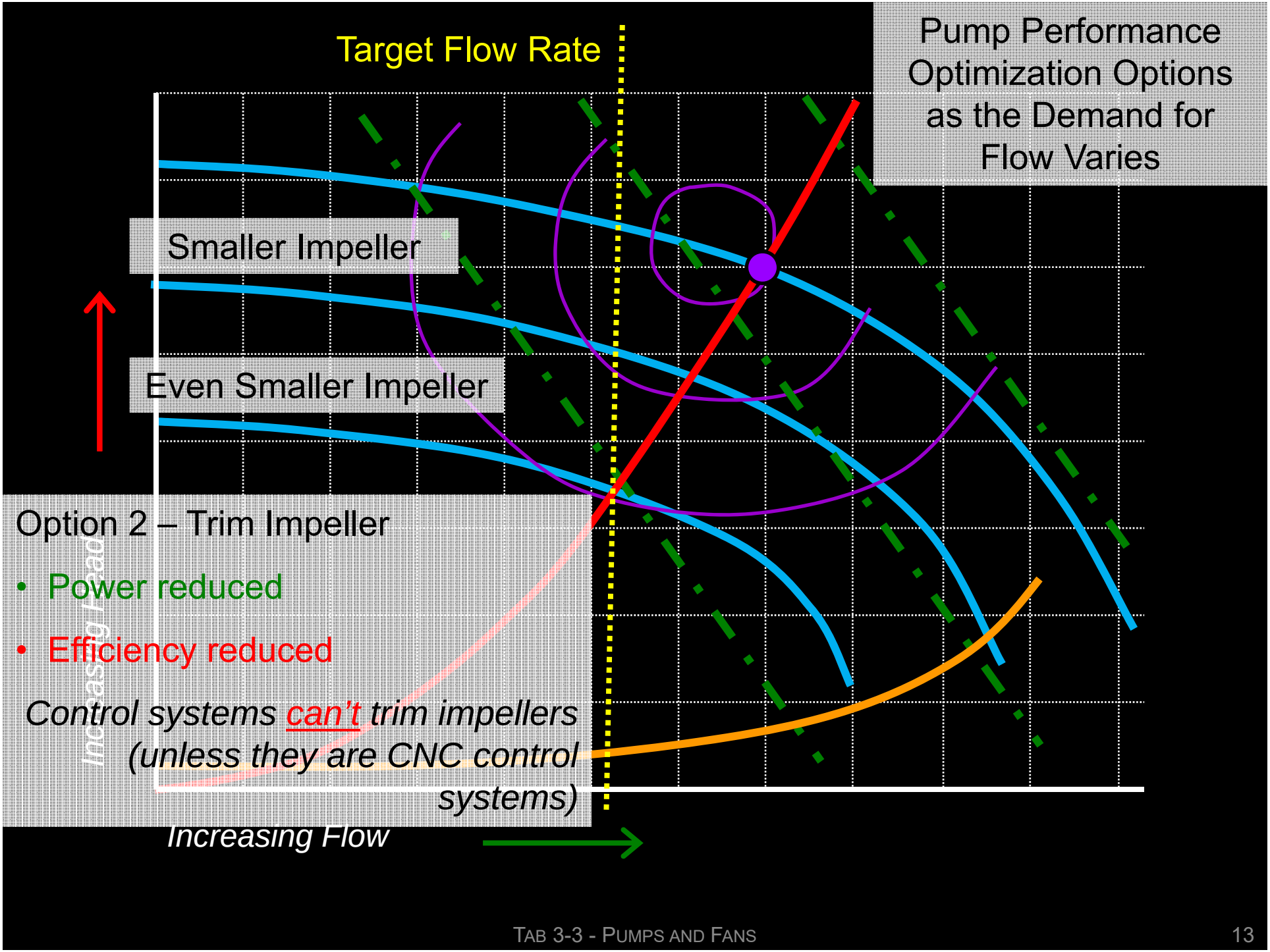
The System Curve:

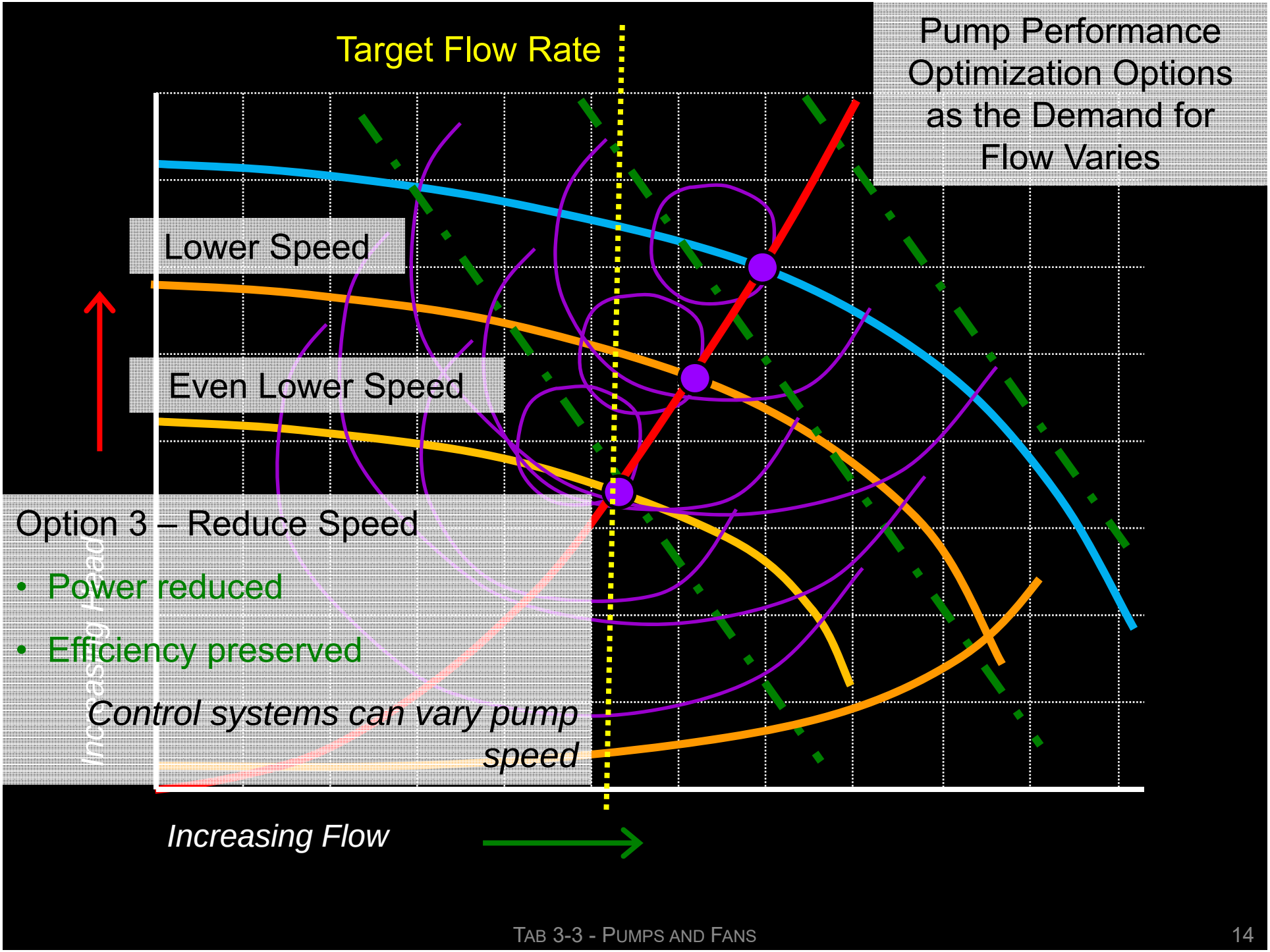
- Statement of the piping network's performance in terms of flow and head
- A function of the physical characteristics of the system design and fabrication
- Projected by design calculations
- Established via field test


Increasing Head
Increasing Flow
Design Goal
• Match operating point to pump peak efficiency point

Pump Performance Optimization Options as the Demand for Flow Varies



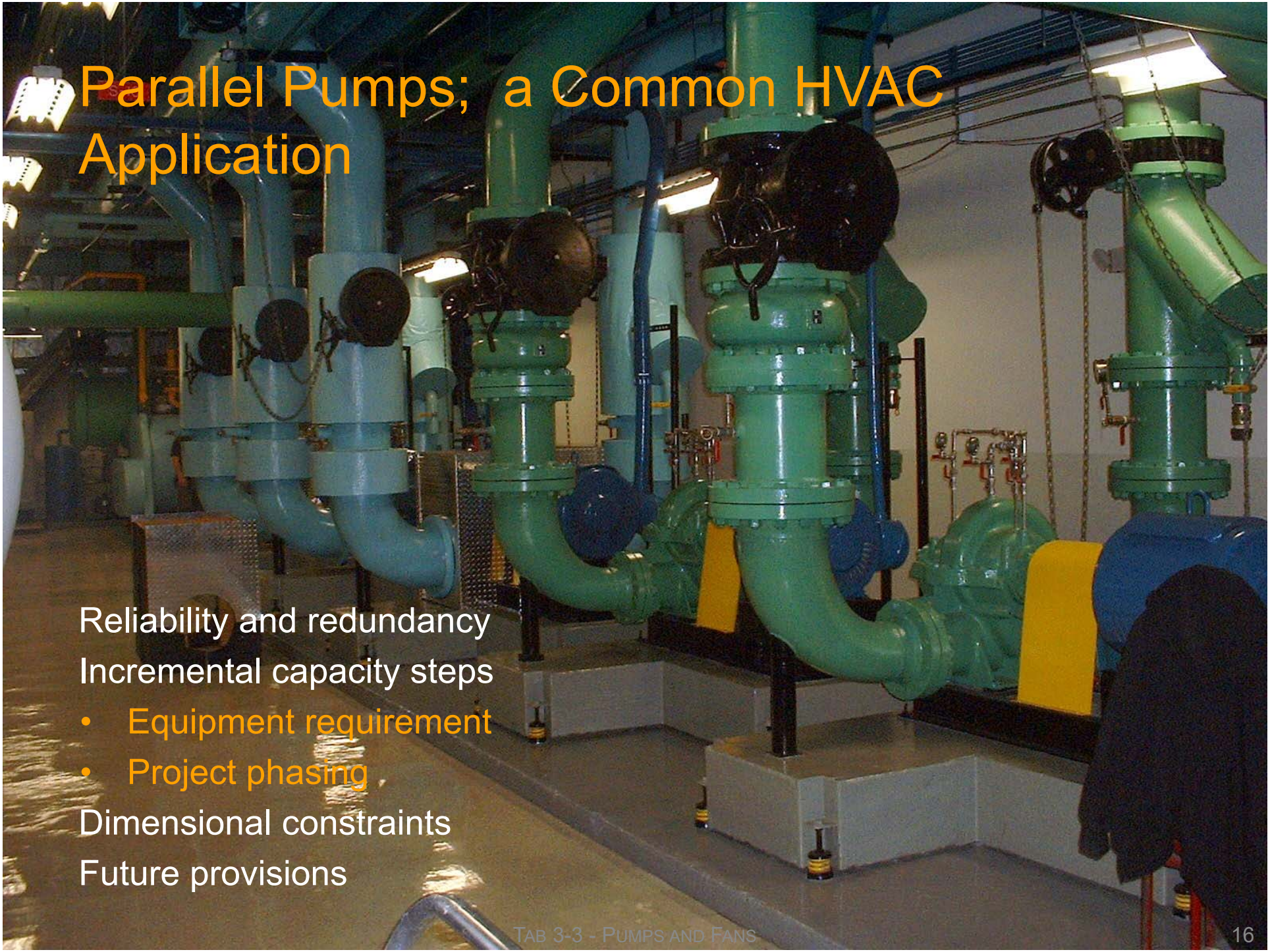

Pump Performance Optimization Options as the Demand for Flow Varies
Target Flow Rate
Smaller Impeller
Even Smaller Impeller
Option 2 – Trim Impeller
• Power reduced
• Efficiency reduced
Control systems can't trim impellers (unless they are CNC control systems)
Increasing Head
Increasing Flow


Pump Performance Optimization Options as the Demand for Flow Varies
Target Flow Rate
Lower Speed
Even Lower Speed
Increasing Head
Option 3 – Reduce Speed
• Power reduced
• Efficiency preserved
Control systems can vary pump speed
Increasing Flow

Pump Performance Optimization Bottom Lines

1. The control system is a key player with regard to reducing pump energy to match it to the current load condition
2. If the cooling design condition is the ASHRAE 0.4% design condition, then the current load condition will be different from design 99.6% of the time

Parallel Pumps; a Common HVAC Application



Reliability and redundancy

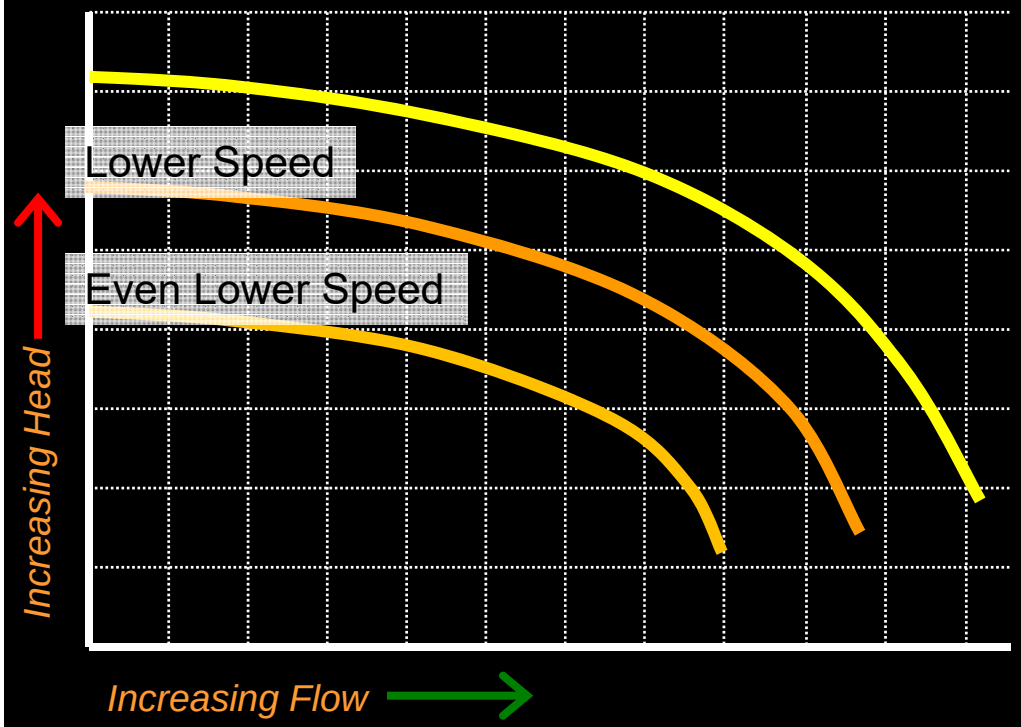
Incremental capacity steps

- Equipment requirement
- Project phasing

Dimensional constraints

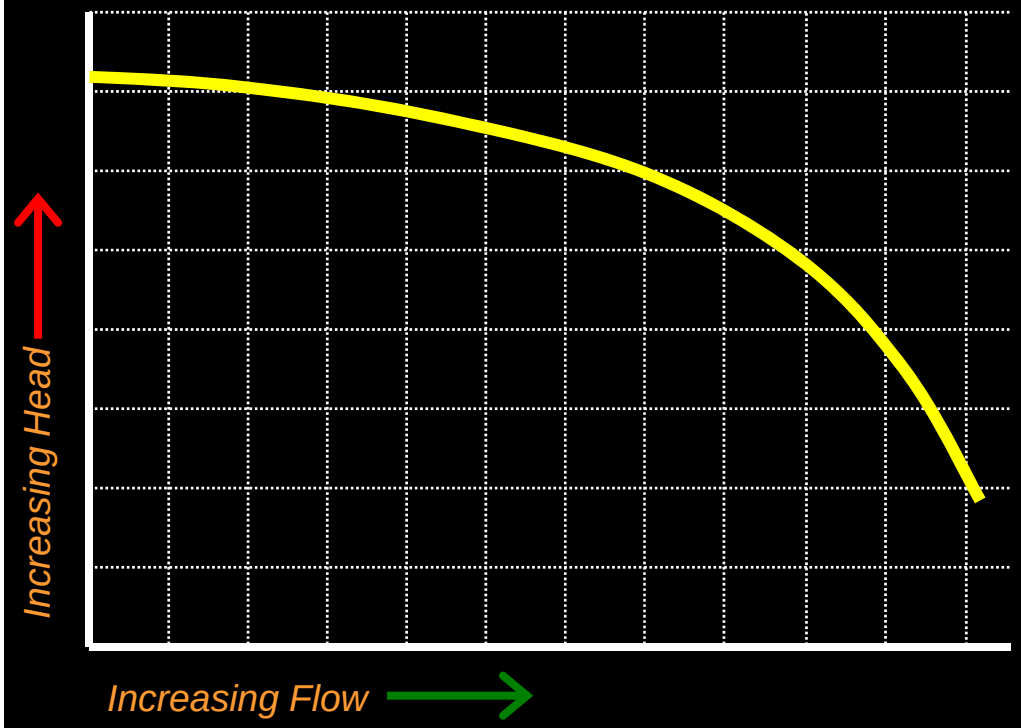
Future provisions

Parallel Pumps



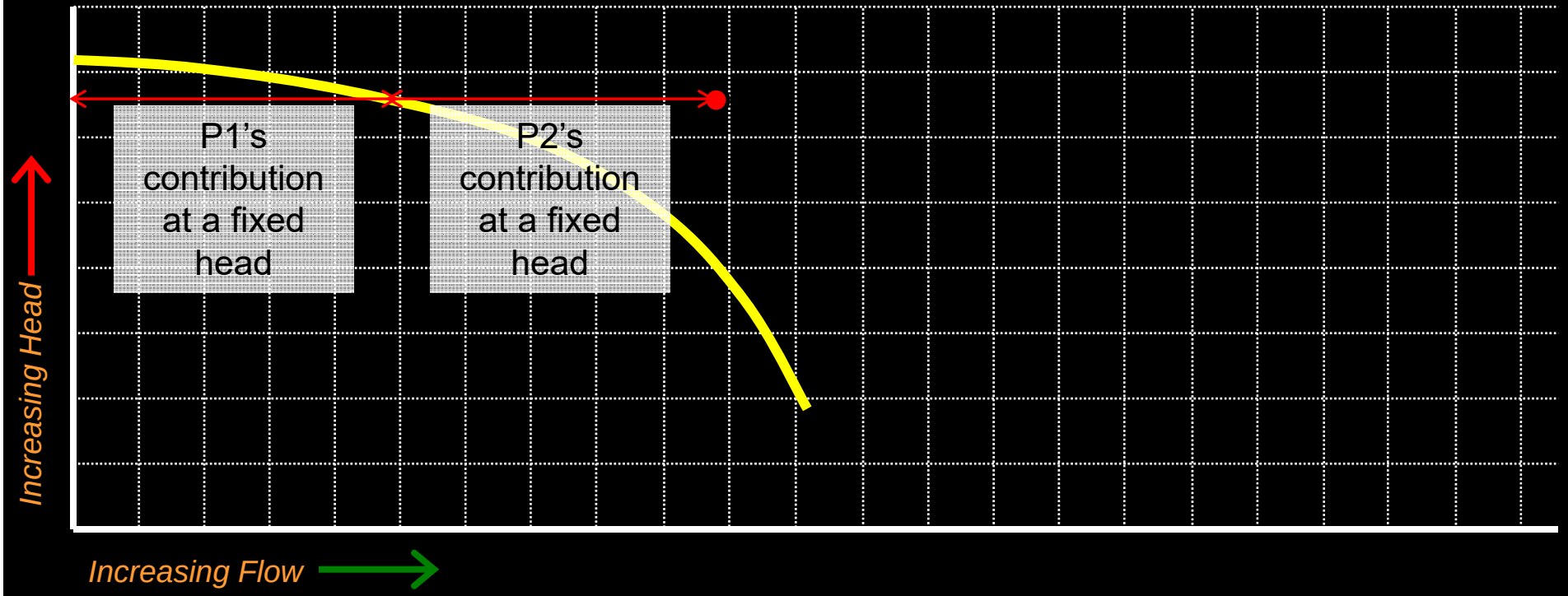
Start with the curve for a single pump at a number of speeds

Parallel Pumps



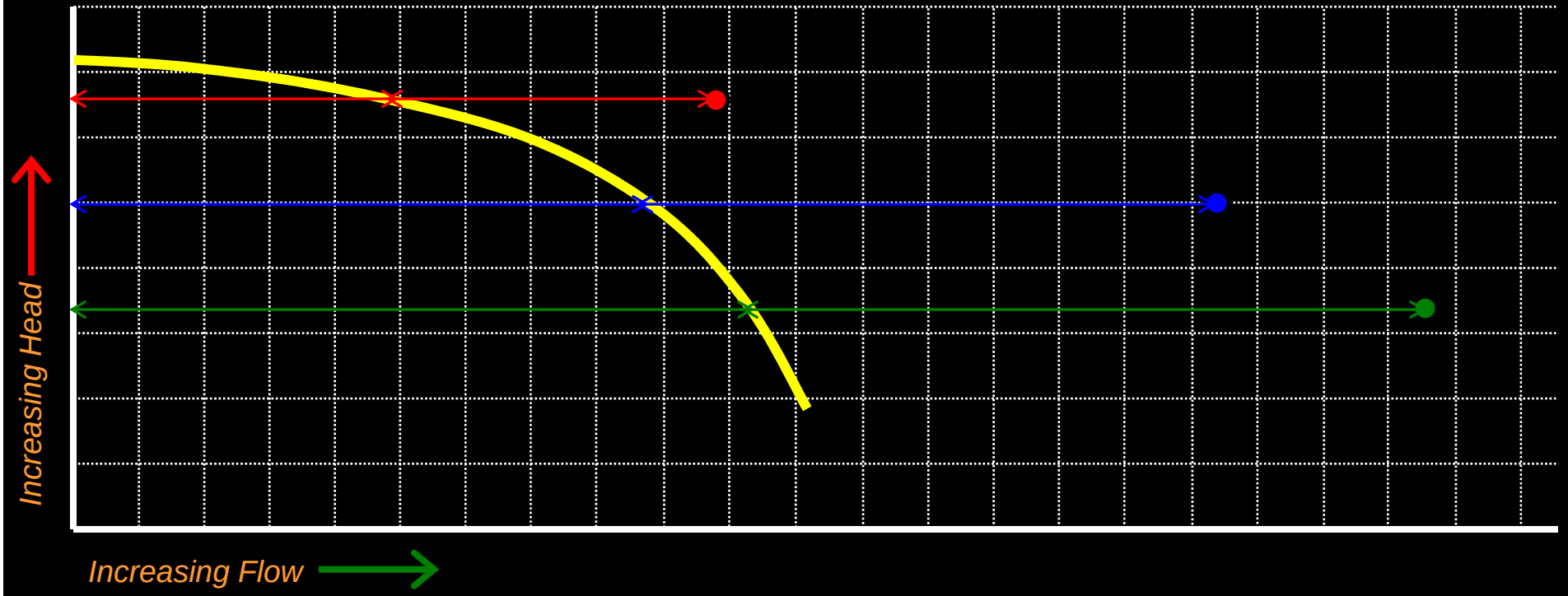
Focusing on the full speed curve …

Parallel Pumps



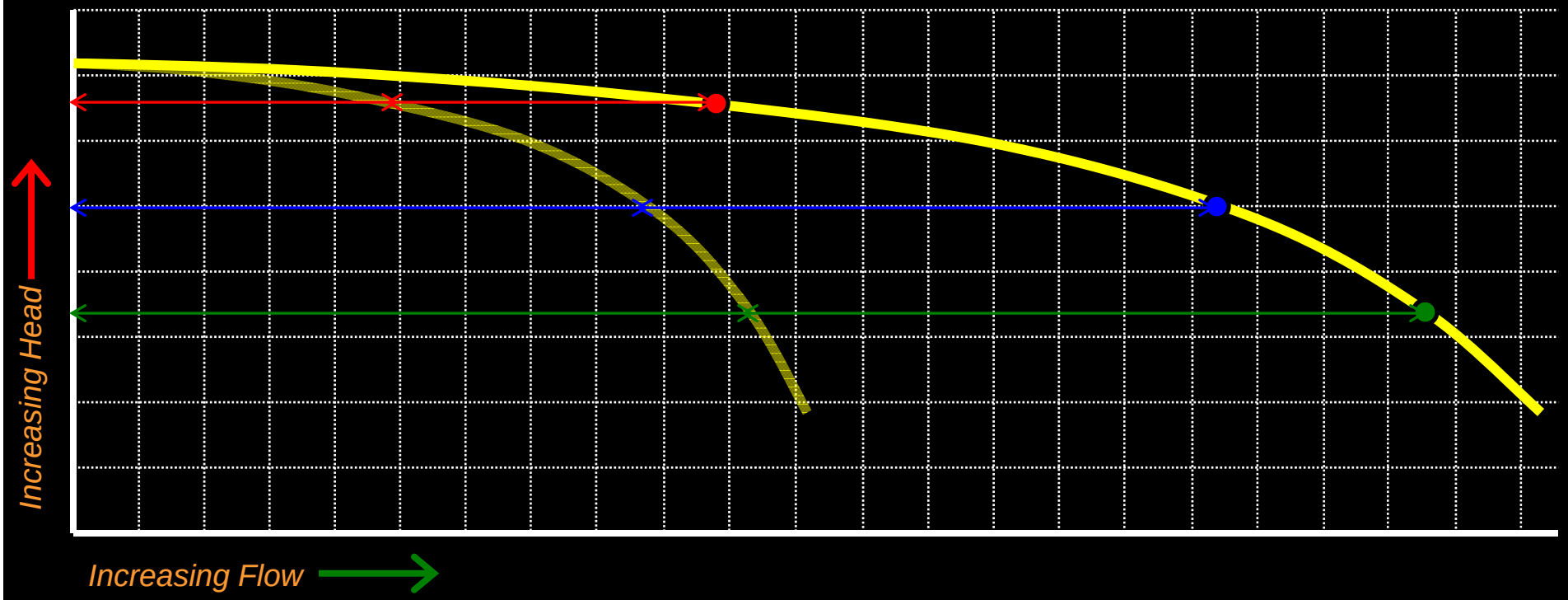
Construct the curve for the same pump at the same speed operating in parallel by doubling the flow at different heads

Parallel Pumps



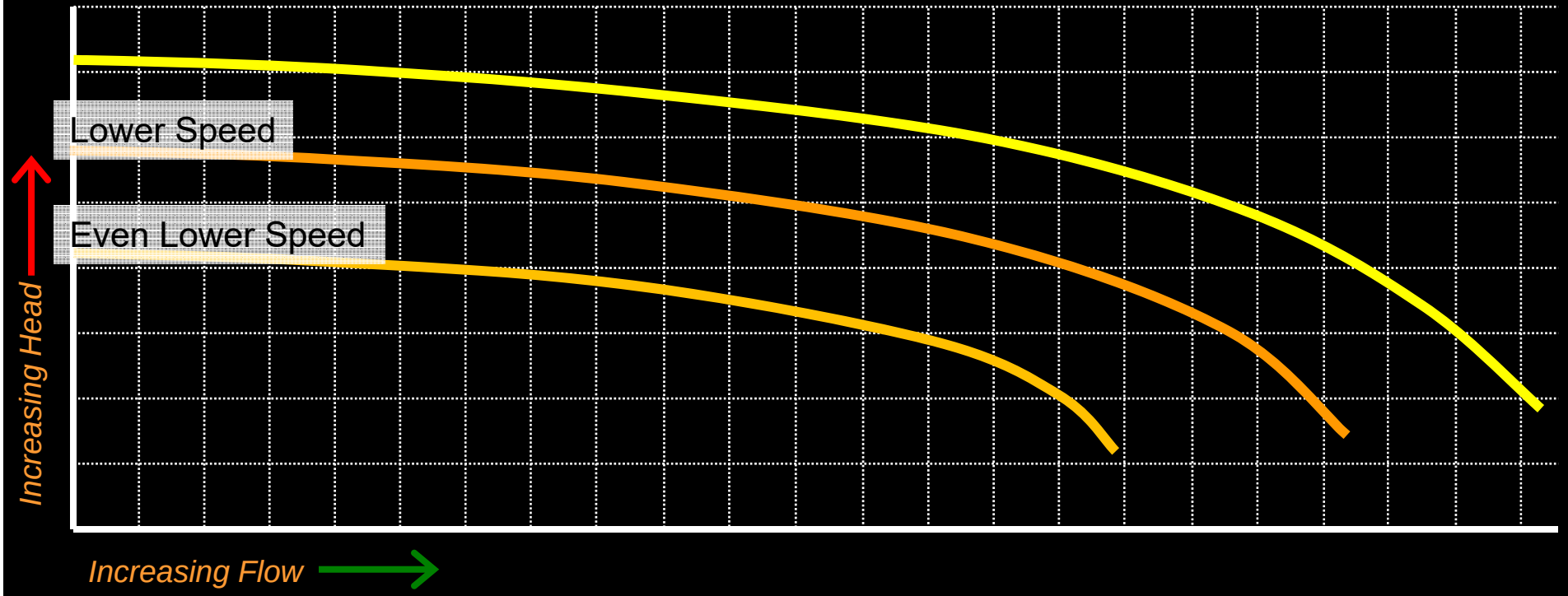
Construct the curve for the same pump at the same speed operating in parallel by doubling the flow at different heads

Parallel Pumps



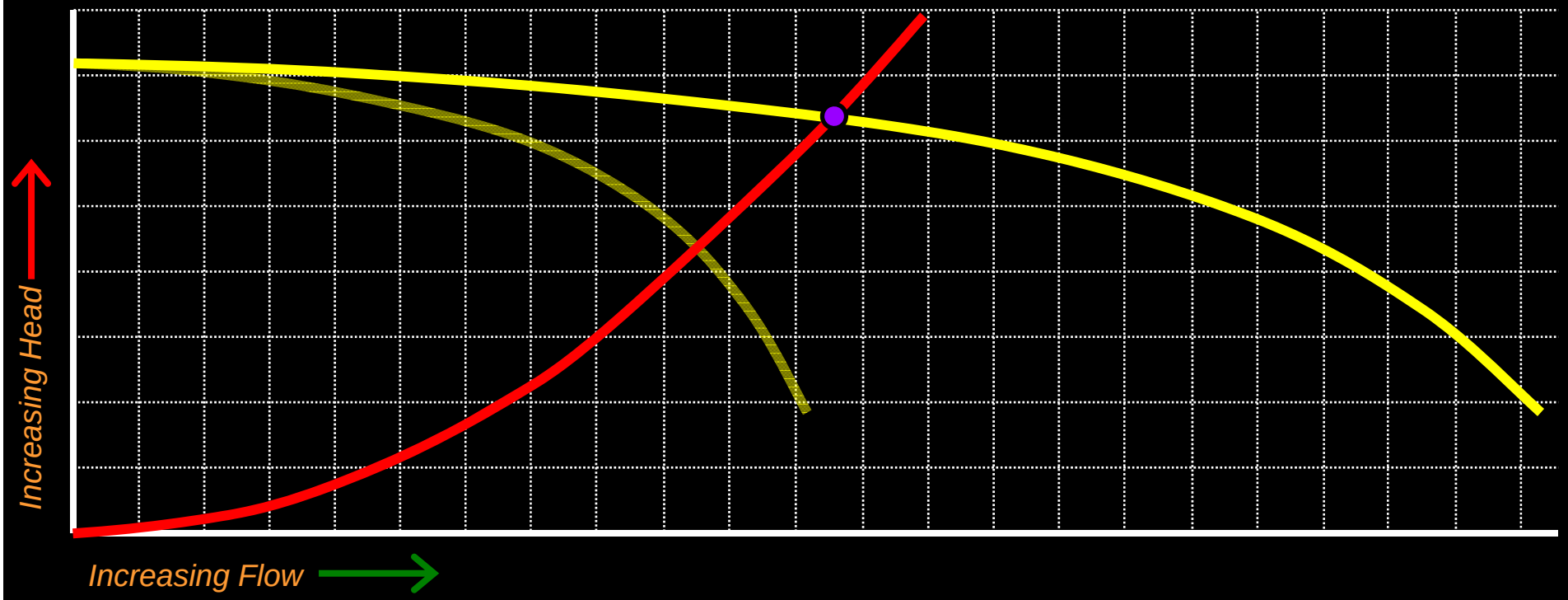
Construct the curve for the same pump at the same speed operating in parallel by doubling the flow at different heads

Parallel Pumps



Varying the speed of both pumps together so they operate at the same speed is similar to the effect for either pump operating on its own; a family of similarly shaped curves

Parallel Pumps



If both pumps are operating at the same speed and one fails, the operating point shifts down the system curve to the point where the single pump curve crosses it; typically more than 50% of the original flow but at less head

Bottom Lines

1. Centrifugal machines are very common in our systems
   a. They operate on a fairly basic principle
   b. If you understand the physics of one particular type, then you probably have a pretty good basic understanding of the others
2. There is more than one way to optimize a centrifugal machine
   a. Not a one size fits all thing
   b. Control systems have an important role to play in many of the optimization strategies
3. Parallel pumps and fans have some interesting interactions that we can leverage if we understand them