

NOTE

The material in this presentation has now been published as an article: Ramey, Joseph T., Variable Frequency Drives for Centrifugal Pumps, *Chemical Engineering*, Vol. 119, No. 12, November 2012, pp. 31-42.

The article contains additions, revisions, and more detail.

Evaluation of VFDs for Pumps

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STS-AIChE PE/PO Workshop
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Notes on the Slides

- The slides have been updated from those used at the workshop to insert some of the information from the discussion period.
- The gentlemen on the next two slides attended as resource experts for the discussion period.

Introduction

Rusty Pevehouse

Account Manager

Summit Electric Supply



Introduction

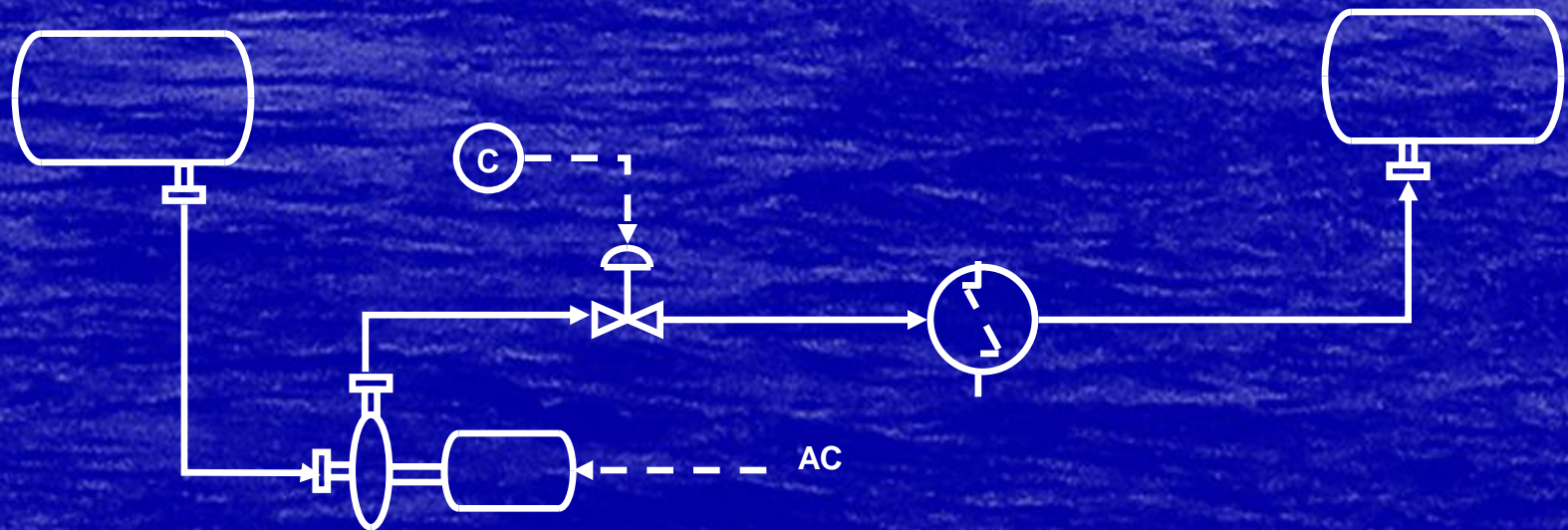
Ivan Cook

Sales

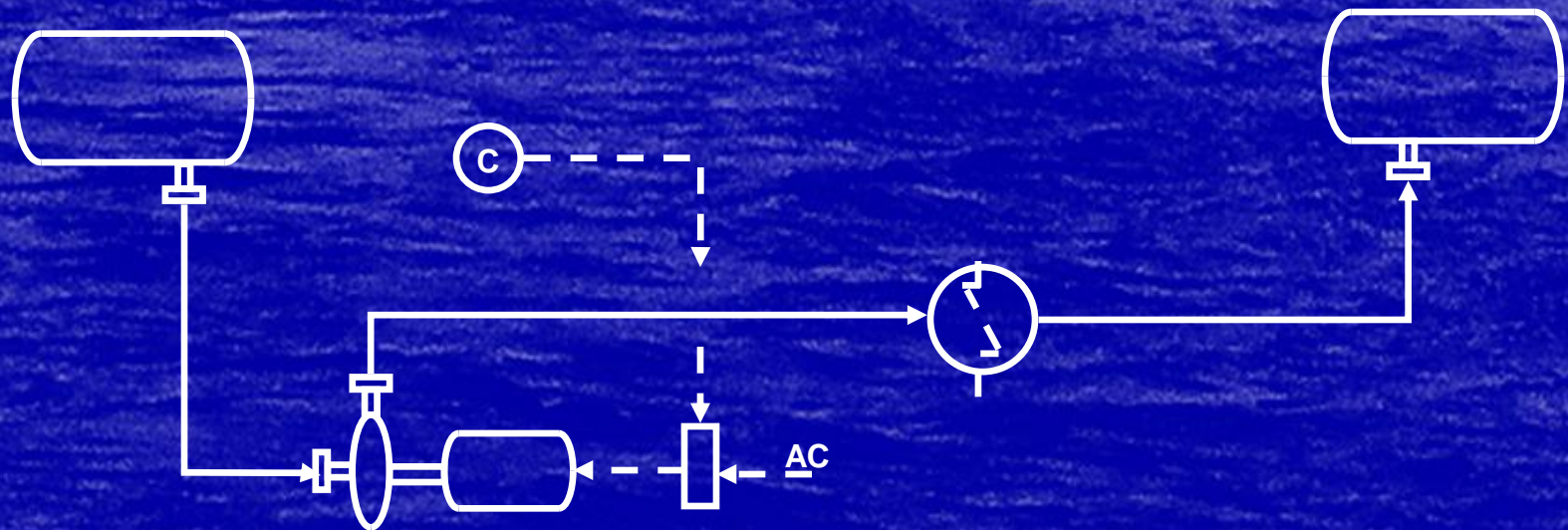
Enhanced Electrical Sales



Introduction

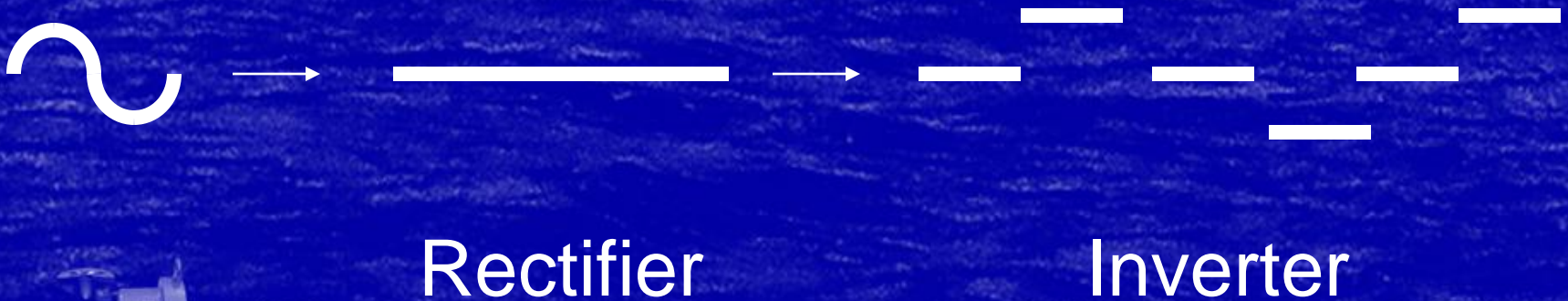


Introduction



VFDs

- What a Process Engineer Needs to Know



VFDs

- Also Called Variable Speed Drives
- Motor Must Operate with an Inverter
 - Auxiliary Fan Motor
- Cable < 150 Ft (50 m)
- Loss is Constant at ~ 1.8% of Max



VFDs

- Solid State. Fan is Only Moving Part
- MTBF \approx 10 Years
- Starter Not Required
- Pump is a Variable-Torque Application
- Refinery 480-Volt Circuits Insensitive
- Turndown is $\sim 120 : 1$



VFDs

- In MCC Building
- No or Low Installation Cost
- Can be a Package
- Failure Mode is to Turn Off
- Operating Error to Max Speed



Pumps

- Principles Applicable to Use of VFDs
- Concentrate on:
 - Centrifugal Pumps
 - Single Stage
 - Continuous Flow



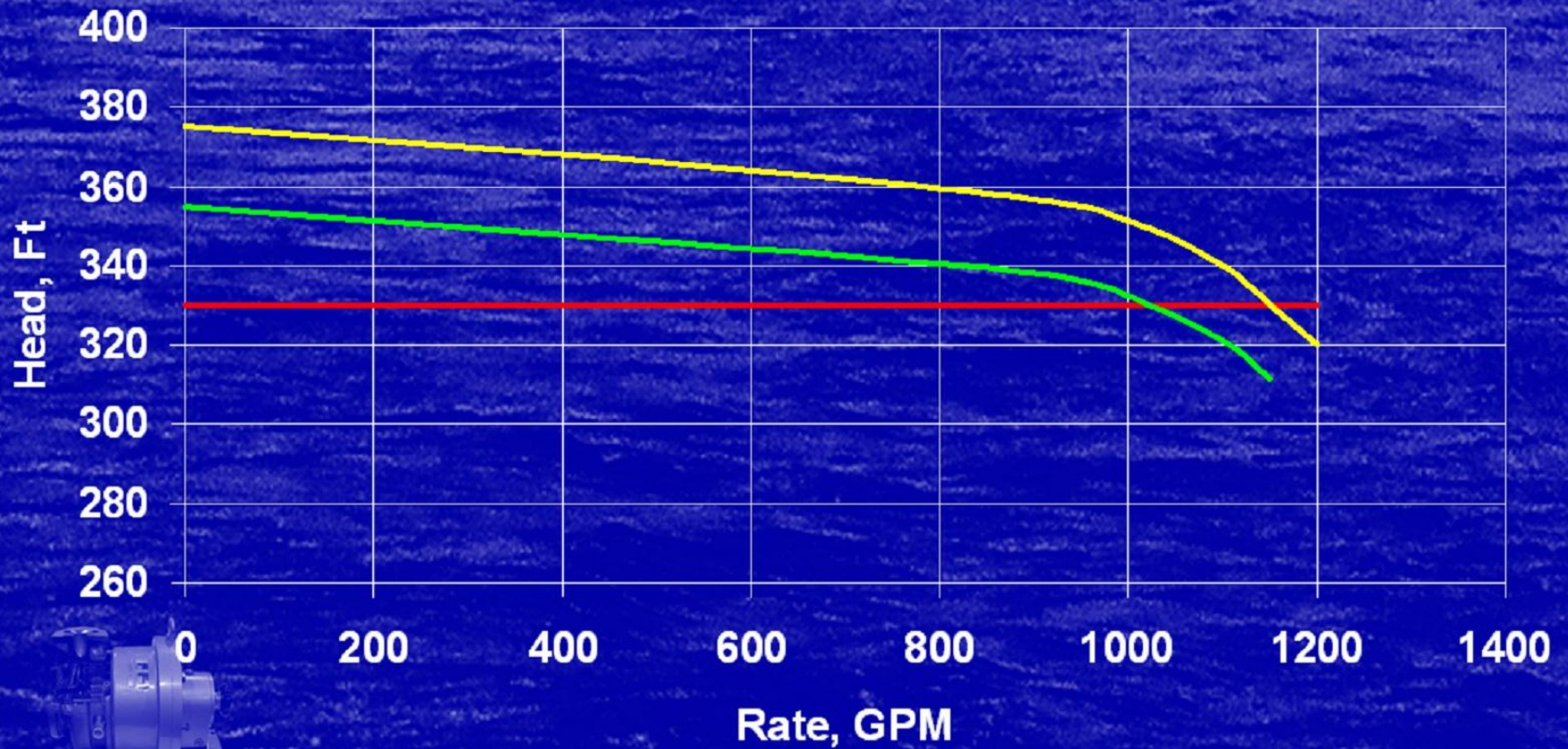
Pumps

Two Bounding Cases

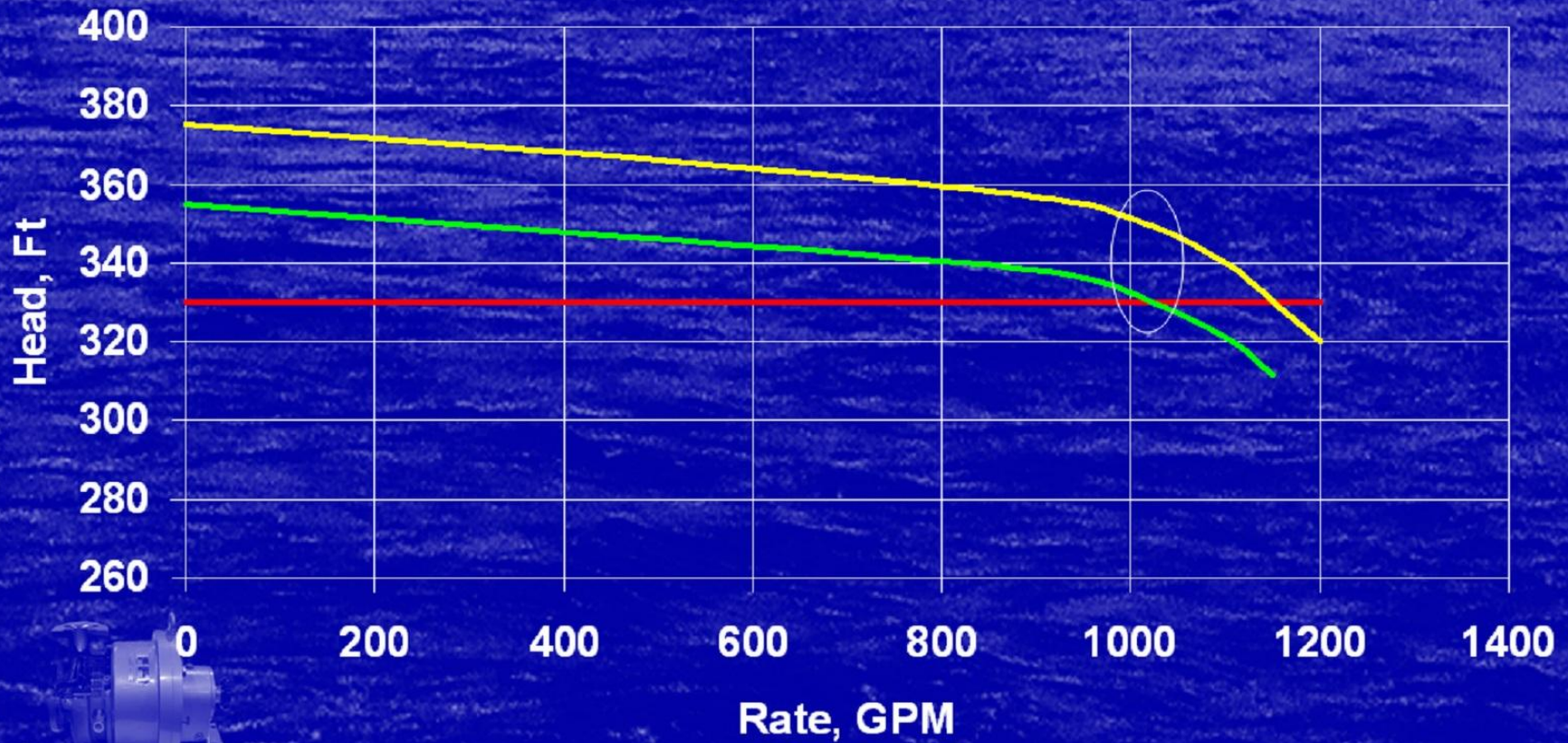
- 0% Frictional Drop (All Static)
- 100% Frictional Drop



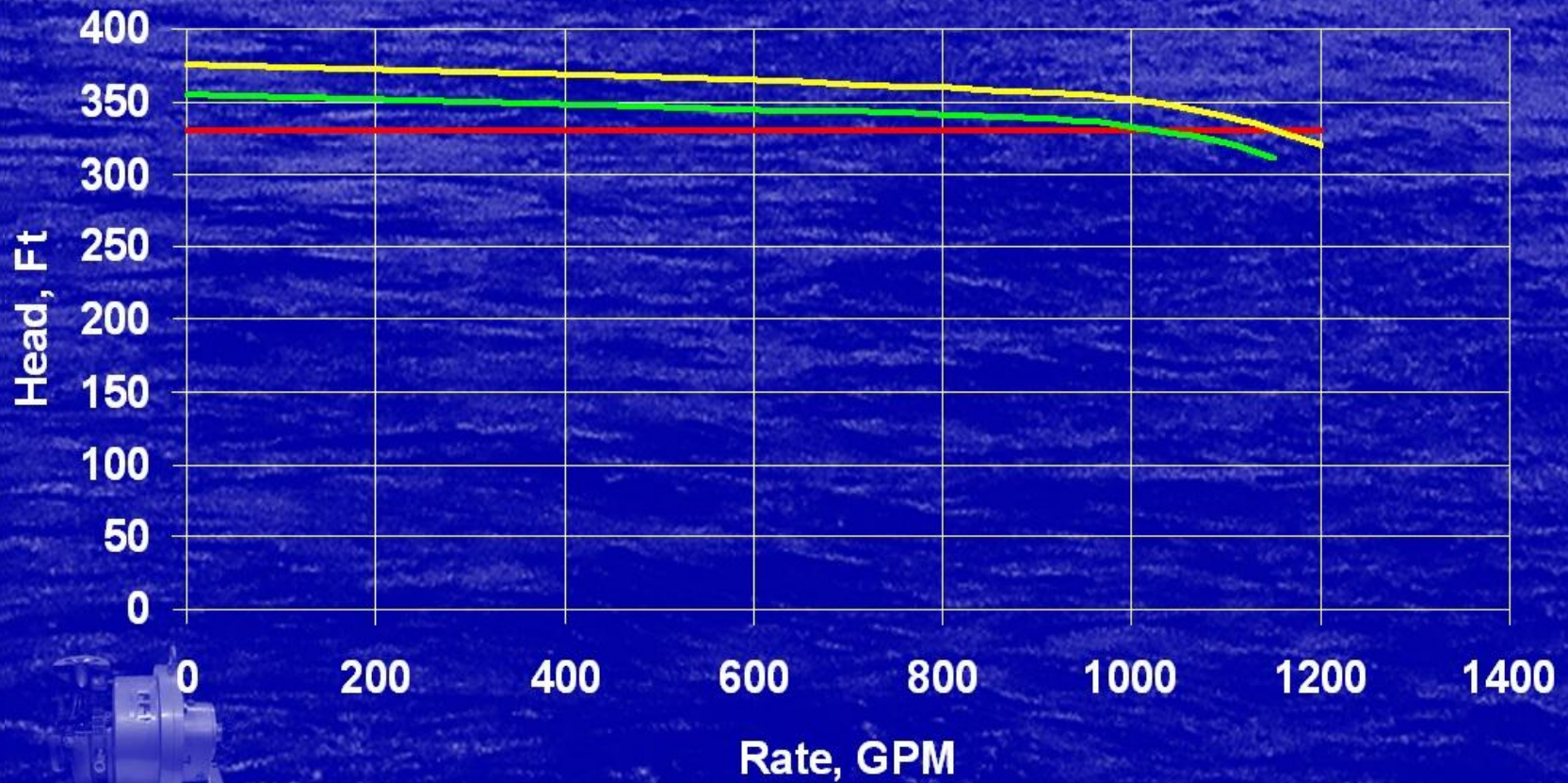
Pumps (All Static Head)



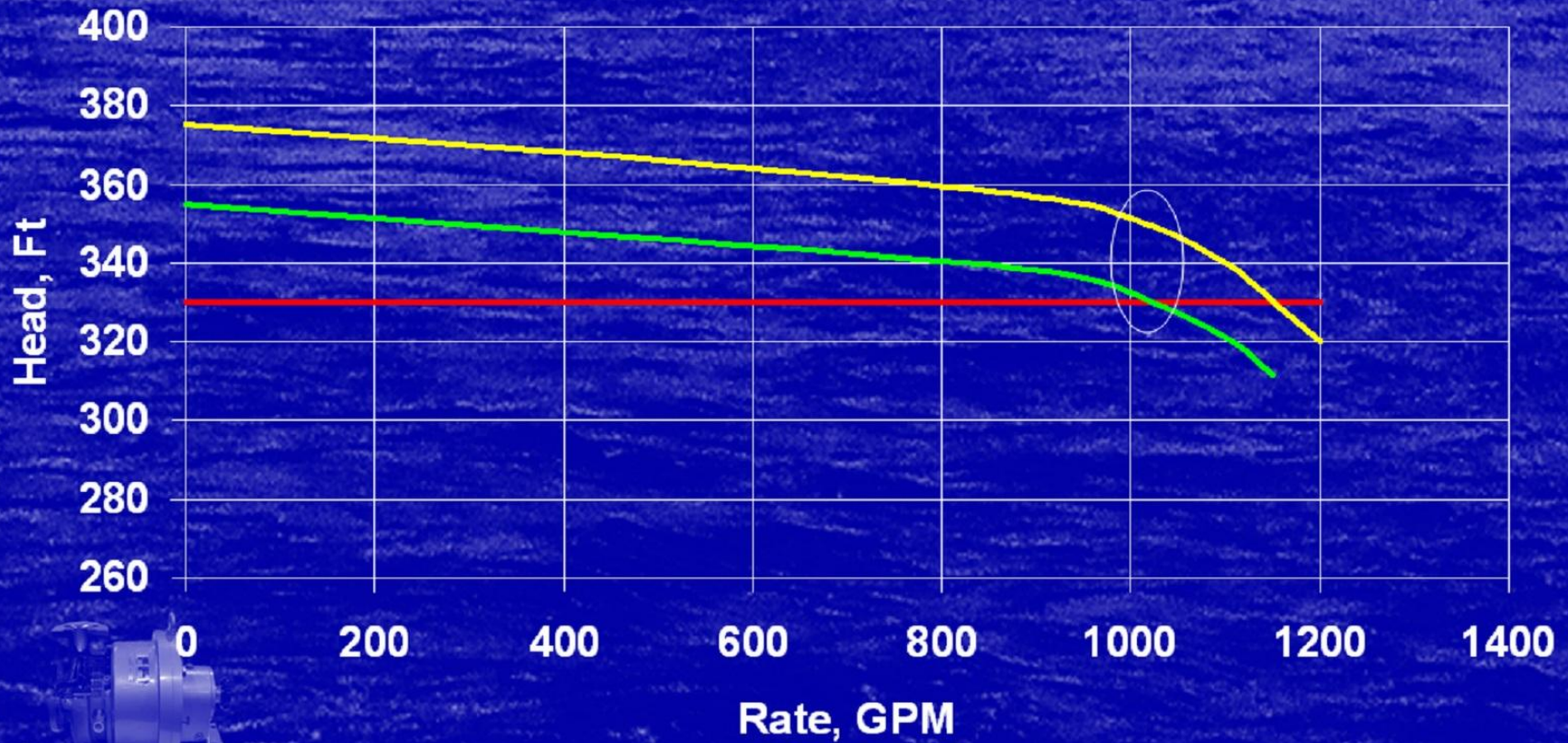
Pumps (All Static Head)



Pumps (All Static Head)



Pumps (All Static Head)



Pumps (Affinity Laws)

$$\frac{Q_2}{Q_1} = \frac{n_2}{n_1}$$

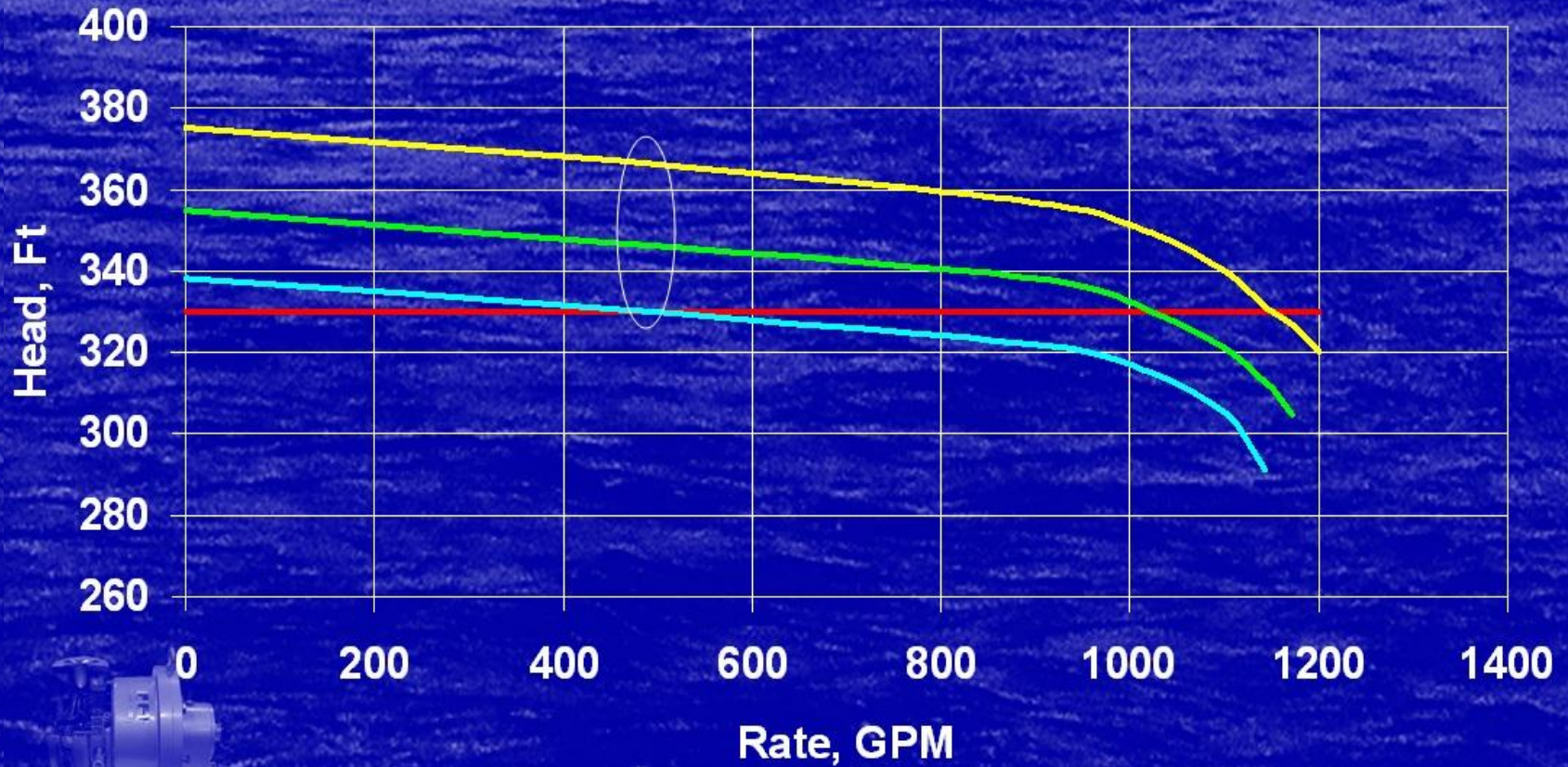
$$\frac{Q_2}{Q_1} = \frac{n_2}{n_1}$$

$$\frac{H_2}{H_1} = \left(\frac{n_2}{n_1} \right)^2$$

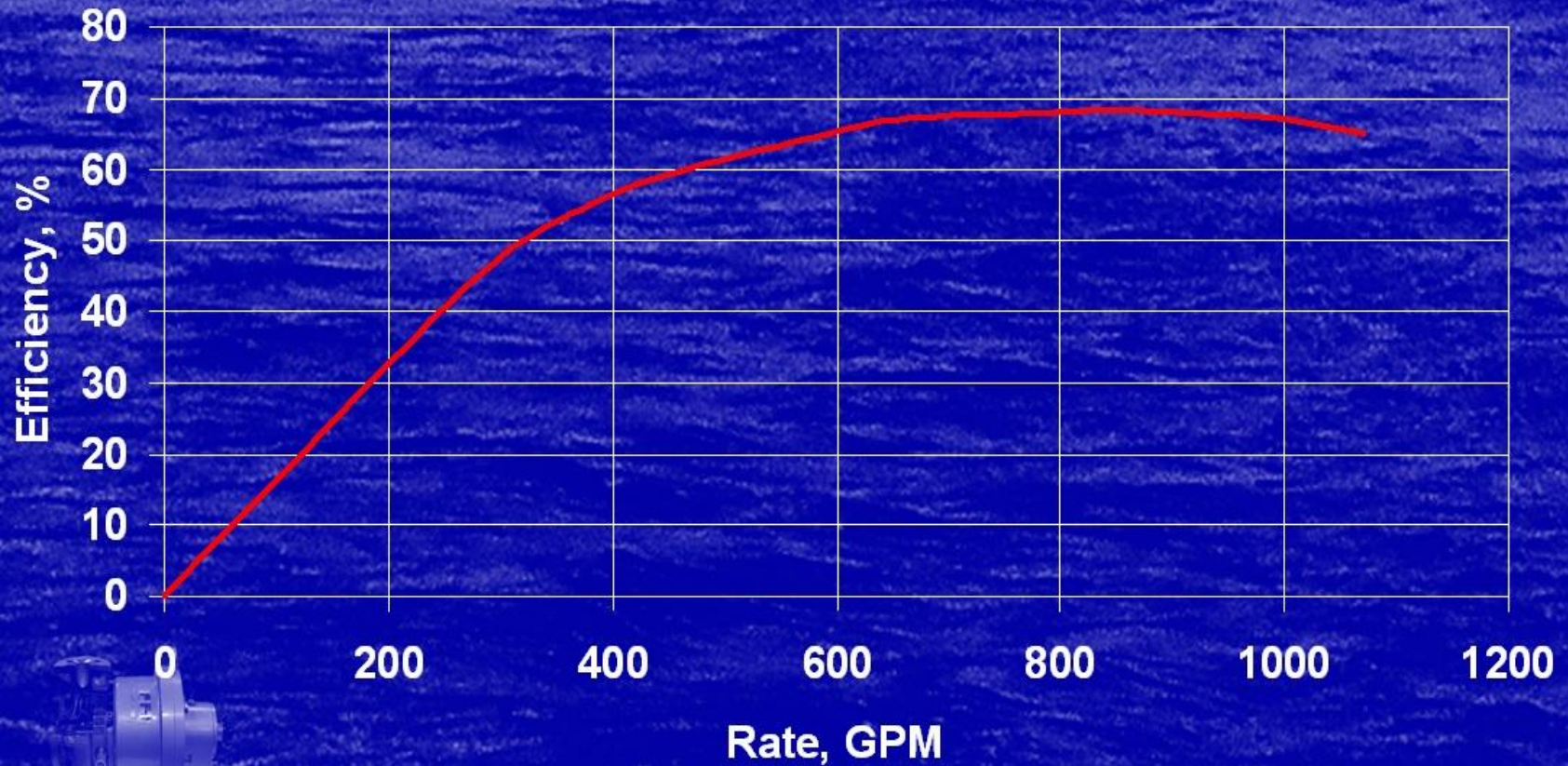


Rase, Howard F., and M. H. Barrow, Project Engineering of Process Plants, John Wiley & Sons, New York, 1957, p. 281

Pumps (All Static Head)



Pumps (Efficiency)



Pumps (Darcy Eq.)

$$\Delta P = 0.000216 f L \rho Q^2 / d^5$$

f Constant for
Turbulent

$$\Delta P = H(SG) / 2.31$$

$$H = \frac{Q^2}{C'}$$

$$\frac{H_2}{H_1} = \left(\frac{Q_2}{Q_1} \right)^2$$



Kern, Robert, How to Compute Pipe Size, Chemical Engineering, Jan. 6, 1975, pp 115-120

Pumps (Affinity Laws)

$$\frac{Q_2}{Q_1} = \frac{n_2}{n_1}$$

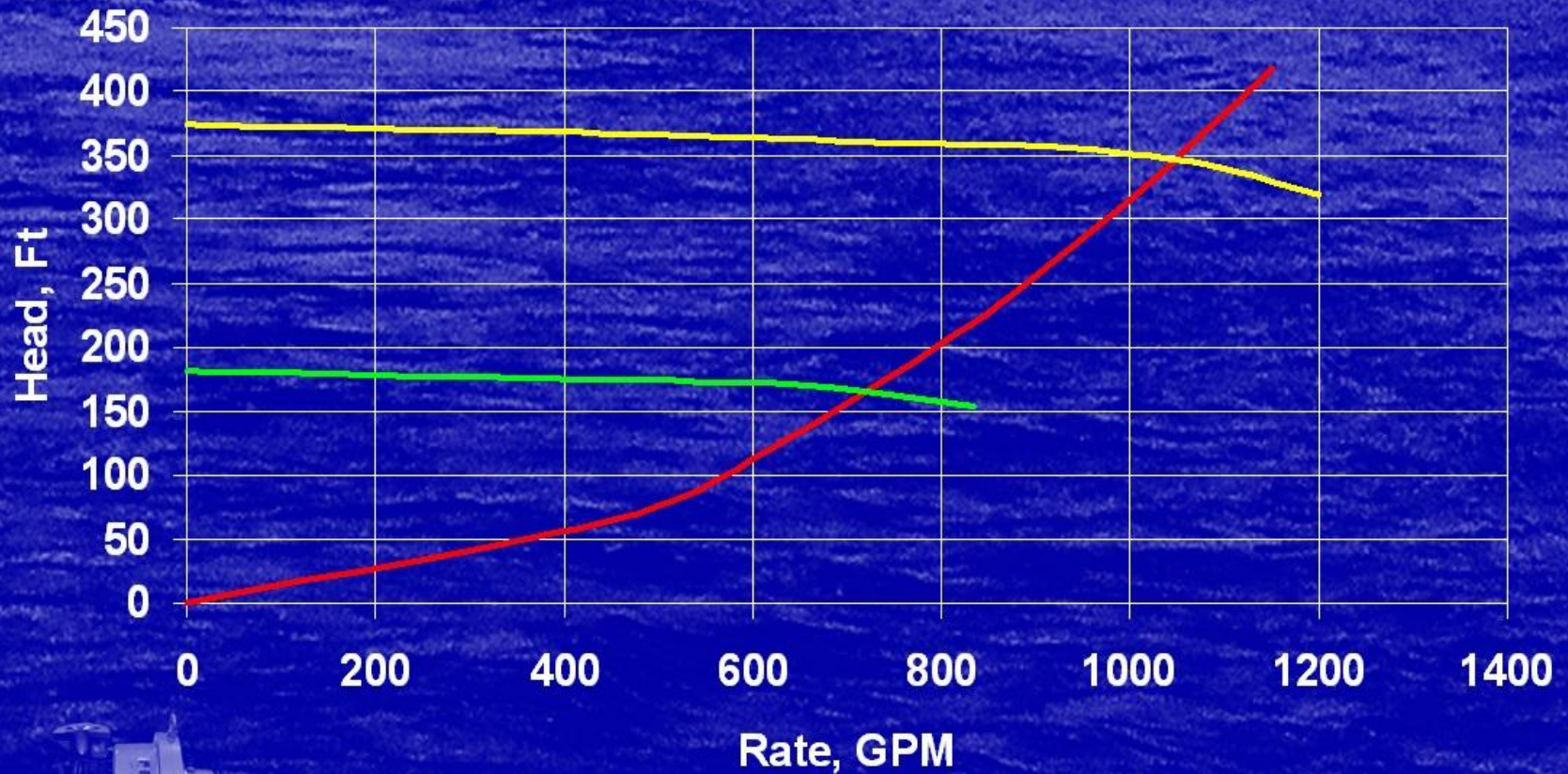
$$\frac{Q_2}{Q_1} = \frac{n_2}{n_1}$$

$$\frac{H_2}{H_1} = \left(\frac{n_2}{n_1} \right)^2 \longrightarrow \frac{H_2}{H_1} = \left(\frac{Q_2}{Q_1} \right)^2$$



Rase, Howard F., and M. H. Barrow, Project Engineering of Process Plants, John Wiley & Sons, New York, 1957, p. 281

Pumps



Pumps

$$HP = \frac{(\Delta P)Q}{1715(\varepsilon_P)(\varepsilon_M)(\varepsilon_V)}$$

$$\frac{Q_2}{Q_1} = \frac{n_2}{n_1}$$

$$HP = \frac{(Q^2)Q}{C''(\varepsilon_P)(\varepsilon_M)(\varepsilon_V)}$$



Rase, Howard F., and M. H. Barrow, Project Engineering of Process Plants, John Wiley & Sons, New York, 1957, p. 259

Pumps

- Minimum Continuous Flow
 - Minimum Continuous Stable Flow
 - Minimum Continuous Thermal Flow
 - Rule-of-Thumb: 30% of BEP Flow
- Minimum Permissible Speed
 - Rule-of-Thumb: 25% of Rated Speed

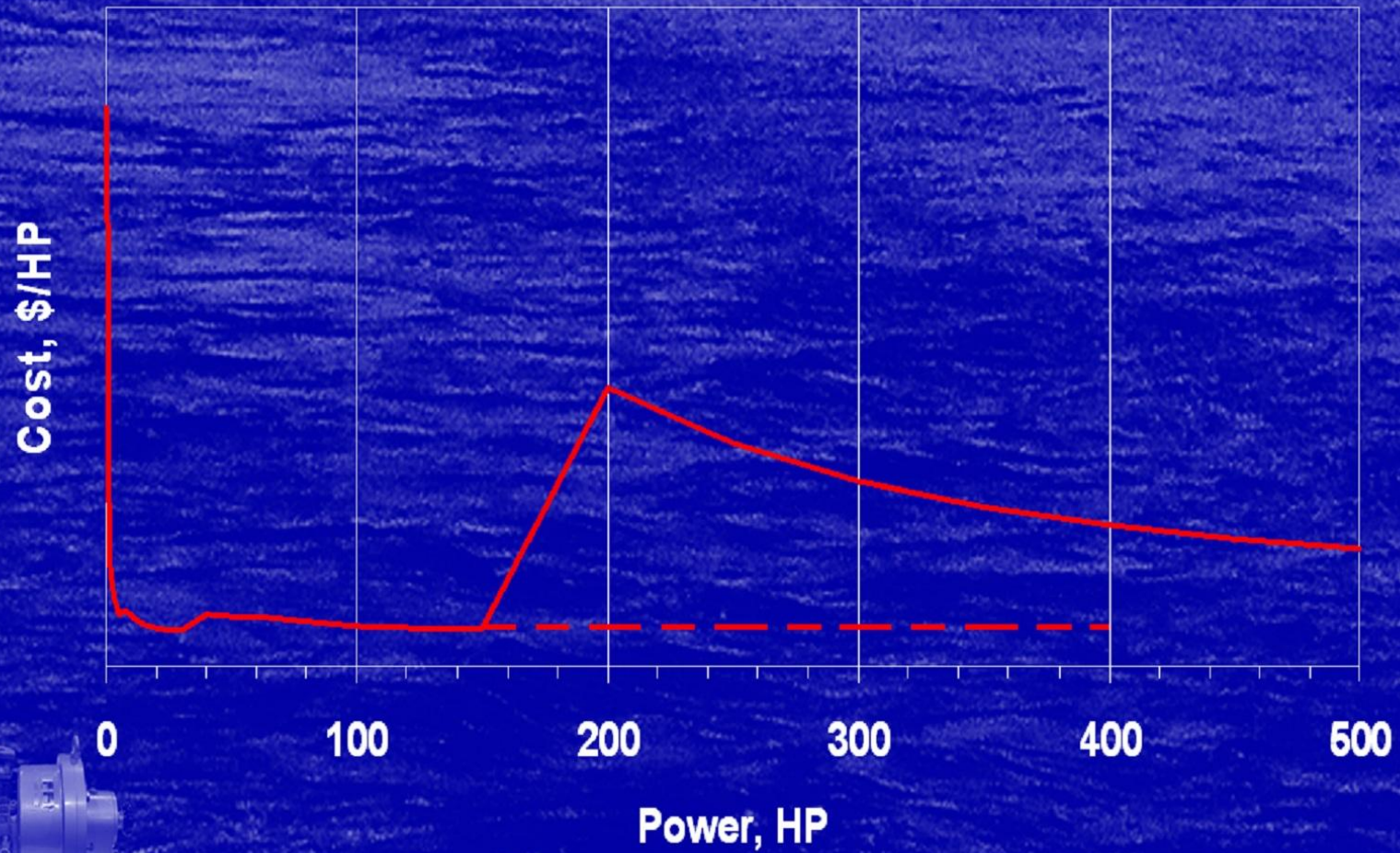


Pumps

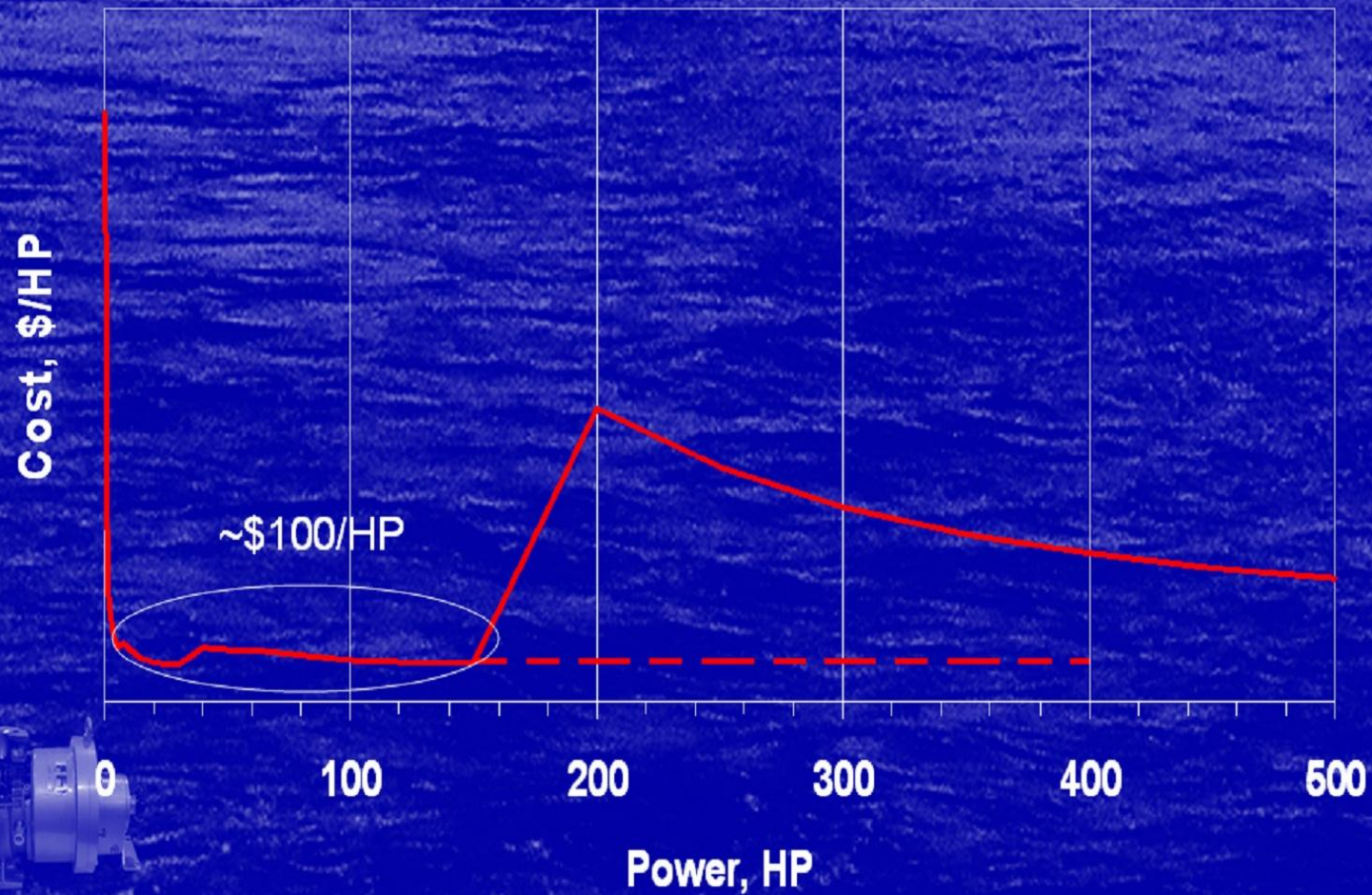
- VFD May Allow a Maximum Impeller



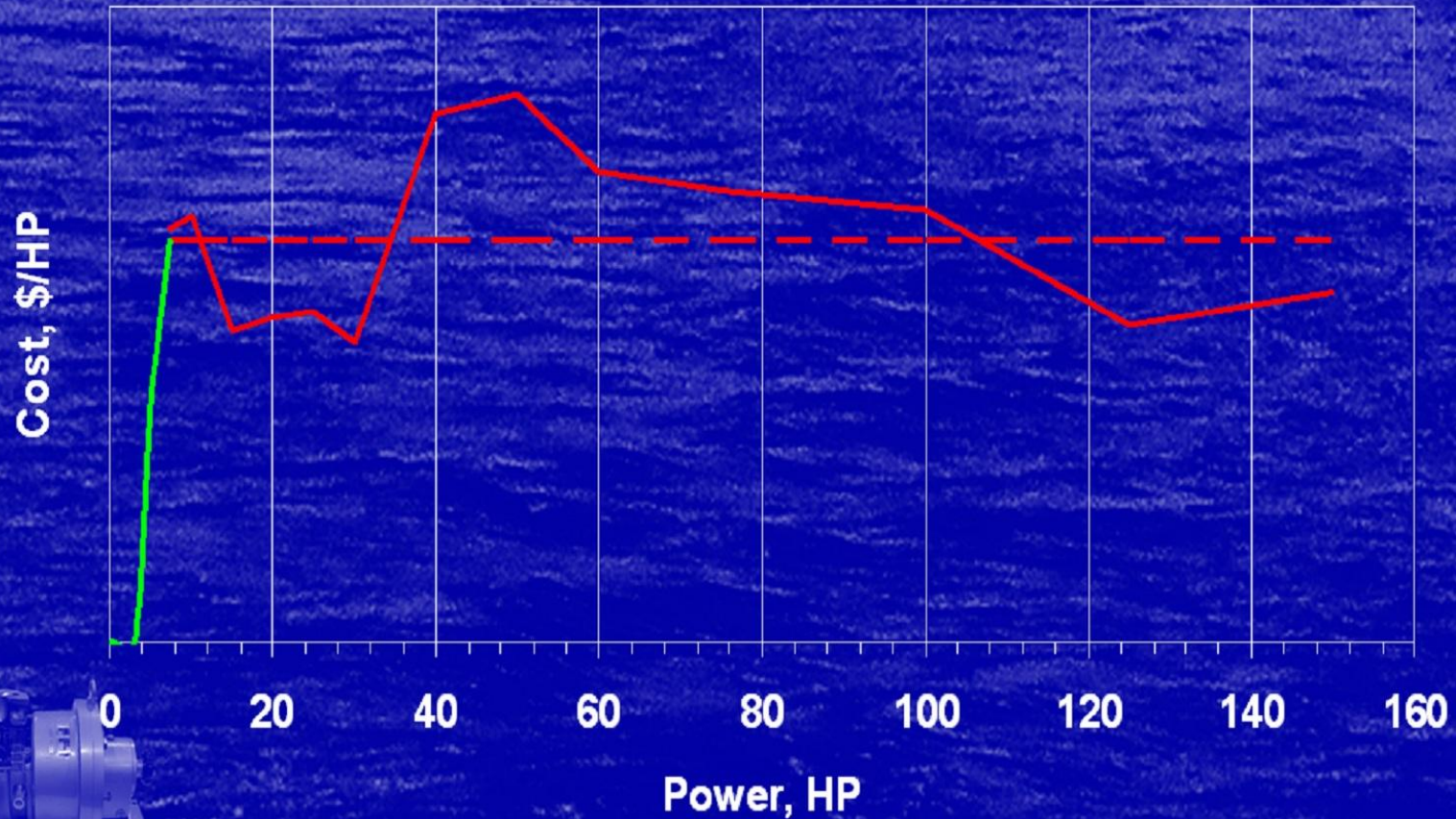
VFD Cost



VFD Cost



(VFD – Starter) Cost



Evaluation – Info by Owner

- Basic Engr. Design Data (BEDD)
- Process Design Basis (PDB)
- Design Standards
- Operating Procedures



Evaluation – Info by Owner

- Power Cost

Marginal Cost
Escalation?

- Payout Period

More Allowed for Power Savings?
Savings Are More Certain



Evaluation – Info by Owner

Owner's Cost Examples (Assumed to Wash for New)

- Project Team
- Management of Change
- HAZOP
- Training
- Drawings & Documents
- Procurement
- Receiving



Evaluation – Info by Owner

- Use 1 or 2 VFDs with Pump and Spare
Method of Starting
Consequences of an Error
- Info on Existing Equip. & Systems
- Approved Vendors
- Cost for Use of Surplus Equipment



Study Considerations

- MCC Building Space at No Cost
- Engineering Washes for New
- Maintenance Washes for New
(Probably Should Have Some Cost)
- VFD Life Assumed Adequate
- No Change in Pipe Diameter Assumed



Study Basis

- New Service
- Power Cost: 7.2 ¢/kW
- Simple Payout: 2 Years
- VFD Located in MCC Building
- Complete CV Station Eliminated

150#

Schedule 40

CS



Study Basis

- Motor Size Does Not Change
- Pump Size Does Not Change
- Higher ΔP & Lower Flow
- Assumed that Separate VFD and Starter Costs Can Represent Modules



Study Basis

- Pump Rated Flow is 10% Above Maximum Normal Flow
- Single-Source Budget-Quality Costs for VFDs, Starters, and Control Valves



Study Method

Case: CV

$$\frac{\text{Capital Cost} + \text{Operating Cost}}{\text{Total Cost}}$$

Case: VFD

$$\frac{\text{Capital Cost} + \text{Operating Cost}}{\text{Total Cost}}$$



Study Method

Debit

Credit

VFD

Starter

CV Station

Δ Power

Total

Total



Three Configurations

- Non-Critical Service – One Pump
One VFD
- Critical Service – Pump and Spare
One VFD
- Critical Service – Pump and Spare
Two VFDs

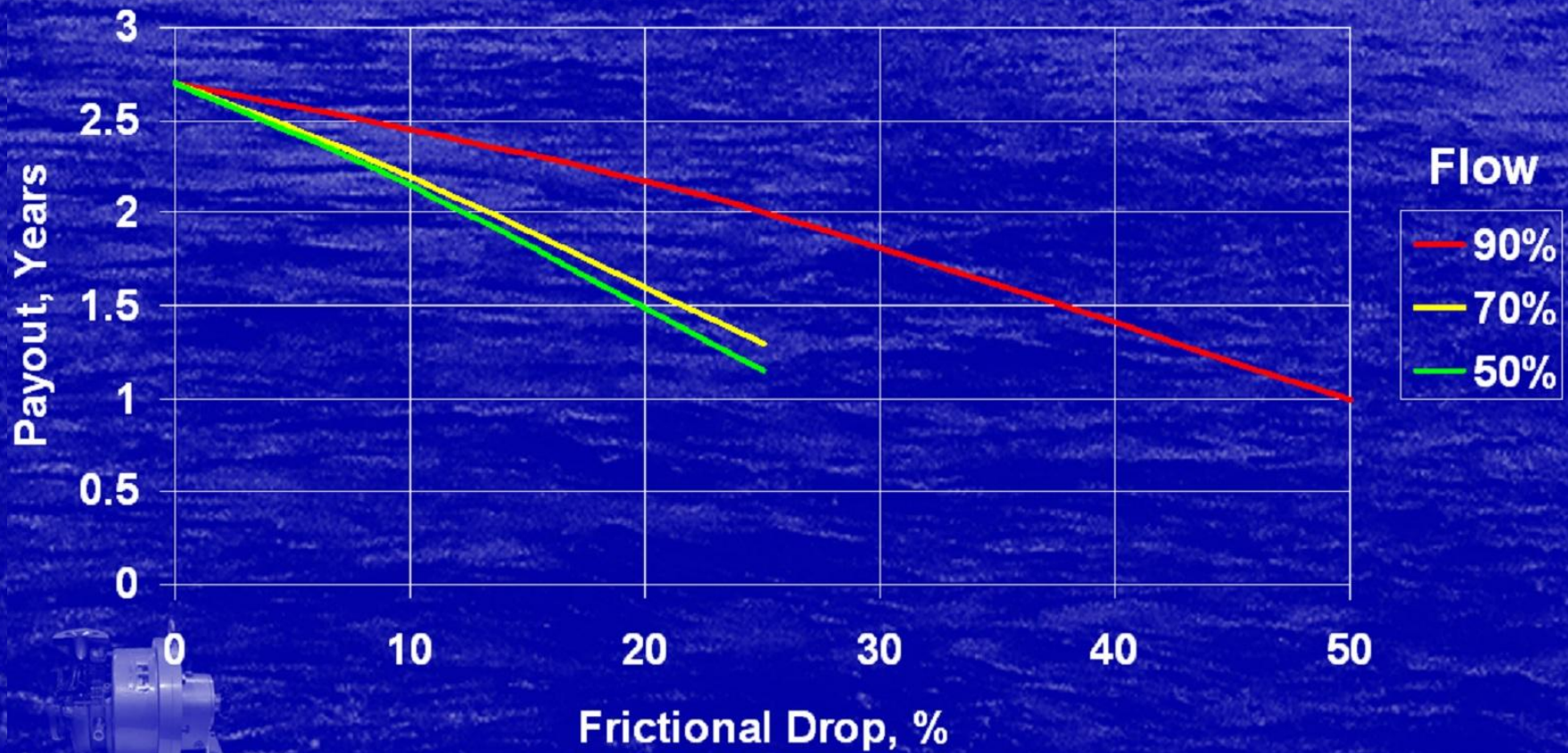


Non-Critical Service – One Pump

- 90% of Rated Flow, 0% Frictional Drop
- Payout = 0.76 Years (9.1 Months)



Critical Service – Pump & Spare



Critical Service – Pump & Spare

VFD Payout in Years

Flow %	Frictional Drop, %		
	0	25	50
90	2.7	2.0	1.0
70	2.7	1.3	-
50	2.7	1.15	-

Other Elements of Cases

- Minimum Flow Bypass
- CV or MFB is Alloy
- Motor Size
- Pump Size



Qualitative Items

- Lower Speed - Less Pump Maintenance
- Soft Start
- Project Schedule
- Potential Vibration
- Manual Operation



Management of Studies

- Low-Voltage VFDs Not That Expensive
- Cannot Justify Detailed Study
- Have to Accept Some Uncertainty
- Evaluating Surplus Pumps May be an Exception
- Of Course, the Design Must be Thorough



Conclusions

- Low-Voltage VFDs are Economically Justified Over a Large Part of Their Range Using Typical Project Economics and Deserve Further Evaluation if Indicated by the Rough Screening.
- However, the Further Evaluation Cannot be Very Detailed and Expensive.



End

