Washington Group International

Integrated Engineering, Construction, and Management Solutions

Impeller Diameter Reduction of a Radioactive Sludge Transfer Pump

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Corollary

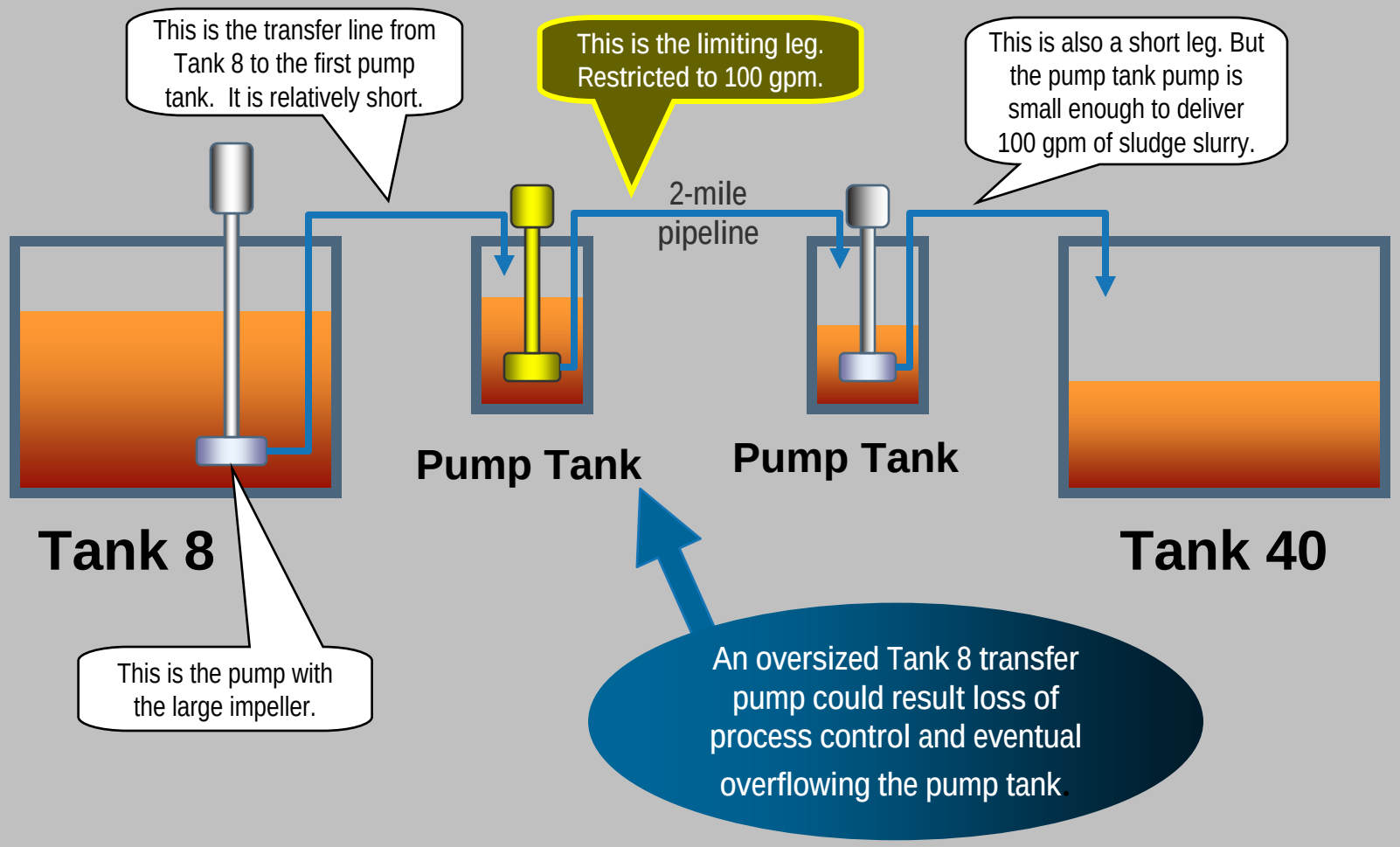
Every project is at least ten times more difficult to implement in the field than <u>ever imagined</u> when first thought of at the desk

Famous Last Words: "…and how hard can that be? "

Summary

The Savannah River Site trimmed the impeller of a radioactive sludge transfer pump from 11 inches in diameter to 8 inches (a reduction of over 25%). This resulted in a more favorable flow and head performance for waste removal operations.

Tank 8 to Tank 40 Transfer Path



Design Restrictions

- tank 8 pump variable speed motor can operate no slower than 1100 rpm
- because of column resonance, motor should not be operated between 1500 and 1800 rpm
- tank slurry conditions highly variable
- the minimum flowrate is 70 gpm

Step by Step

Step 1 – identify slurry conditions

Percent Solids	Yield Stress (dynes/cm^2)	Consistency (cP)	Specific Gravity	Static Head (ft)
5	6	3	1.1	3.8
10	14	5	1.2	6.2
15	32	8	1.4	20.4
18	51	10	1.5	20.4

Operating Band

Step 2 - develop system curve

- Texas A&M flow model corrected for sludge simulant empirical data

Governing Equations – Friction Factors

<u>laminar flow</u> friction factor from the Buckingham equation

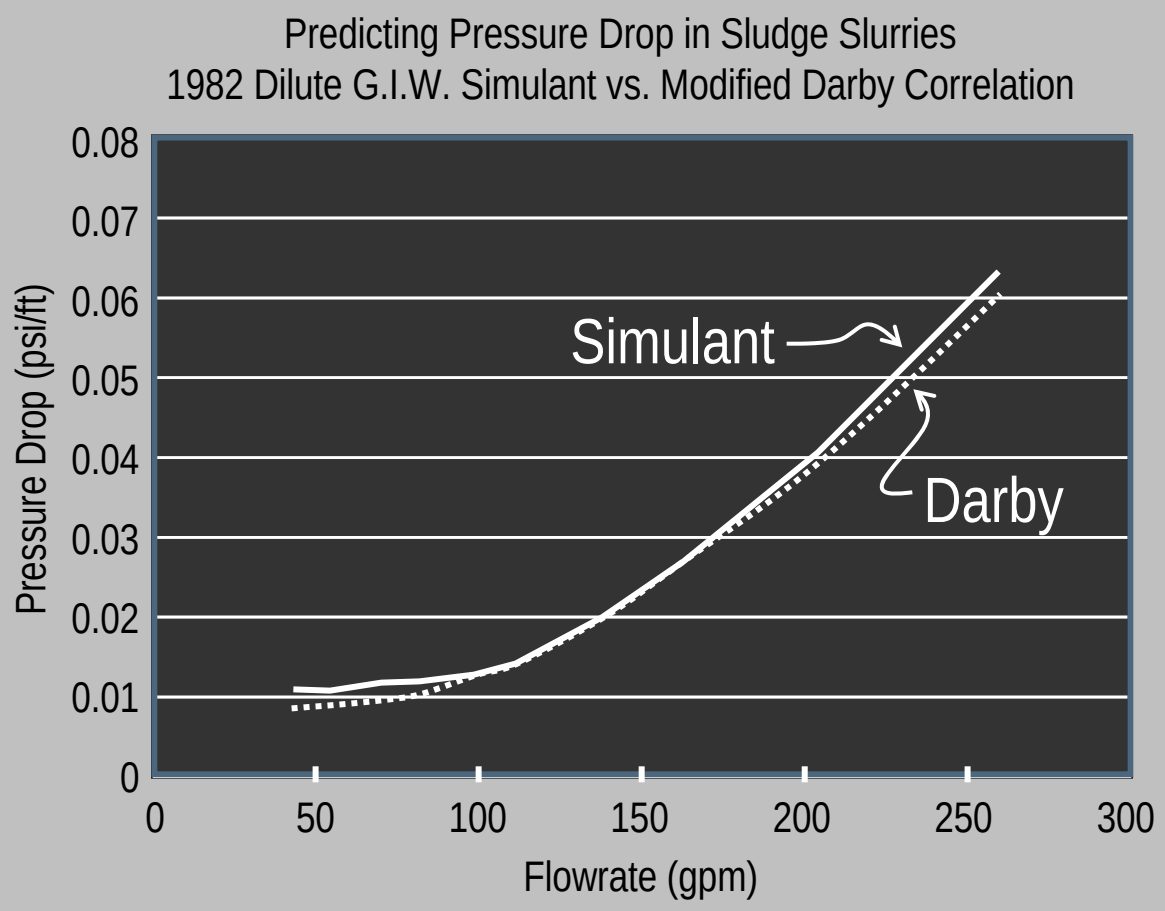
$$f_{\mathrm{L}} = \frac{16}{N_{\mathrm{Re}}}\left[1 + \frac{N_{\mathrm{He}}}{6\,N_{\mathrm{Re}}} - \frac{N_{\mathrm{He}}^{4}}{3\,f_{\mathrm{L}}^{3}\,N_{\mathrm{Re}}^{7}}\right]$$

<u>turbulent flow</u> friction factor from test data

$$f_{\mathrm{T}} = 10^{a}\,N_{\mathrm{Re}}^{-0.193} \quad \text{where}$$

$$a = -1.53\left[1 + 0.146\,e^{-2.9\times10^{-5}\,N_{\mathrm{Re}}}\right]$$

Curve Fitting the Friction Factor



Governing Equations – Pipe Flow

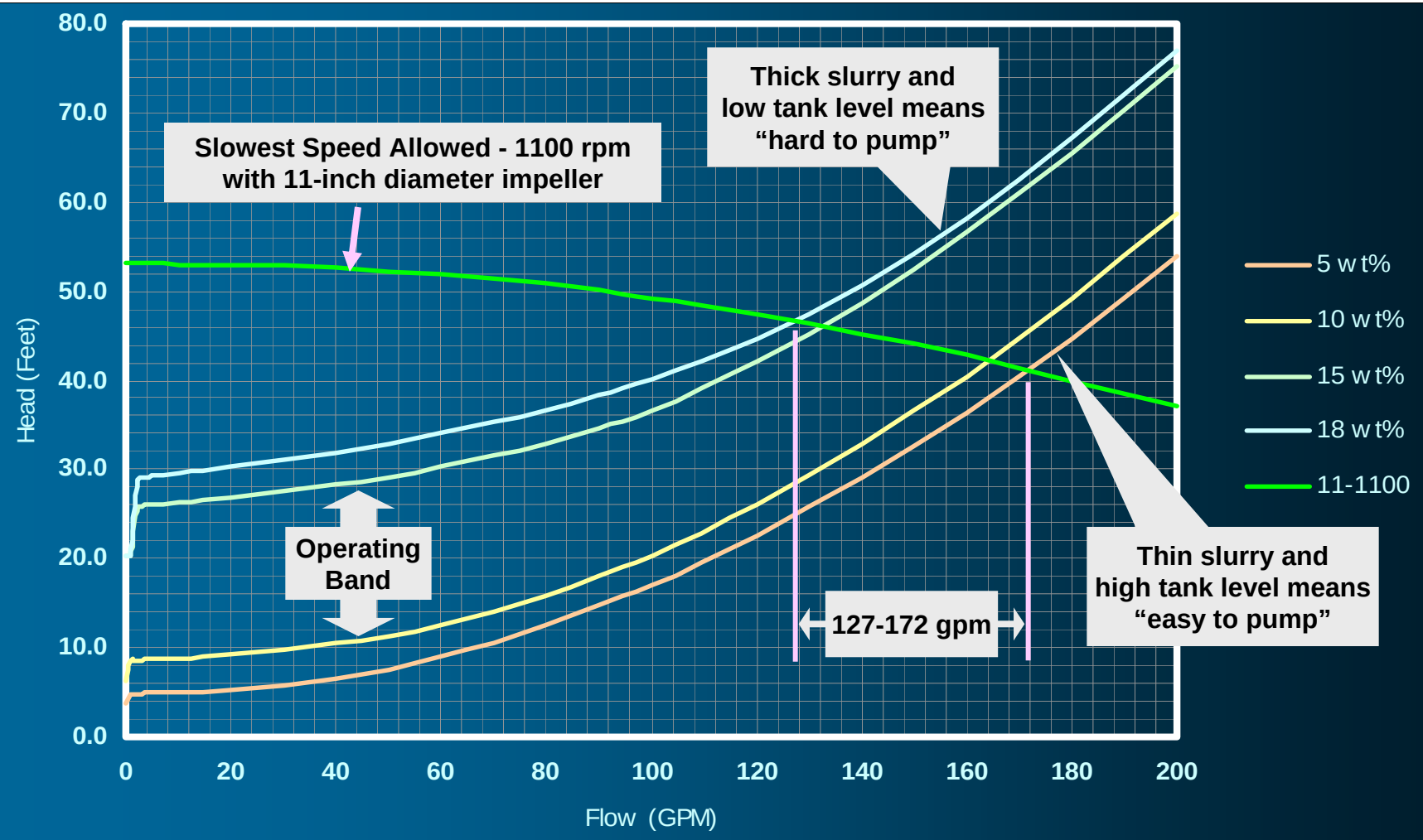
Reynolds number for Bingham plastic fluid in pipes

$$N_{\mathrm{Re}\,BP} = \frac{4Q\rho}{\pi D\eta\left[1+\dfrac{\pi D^3\tau_0}{24Q\eta}\right]}$$

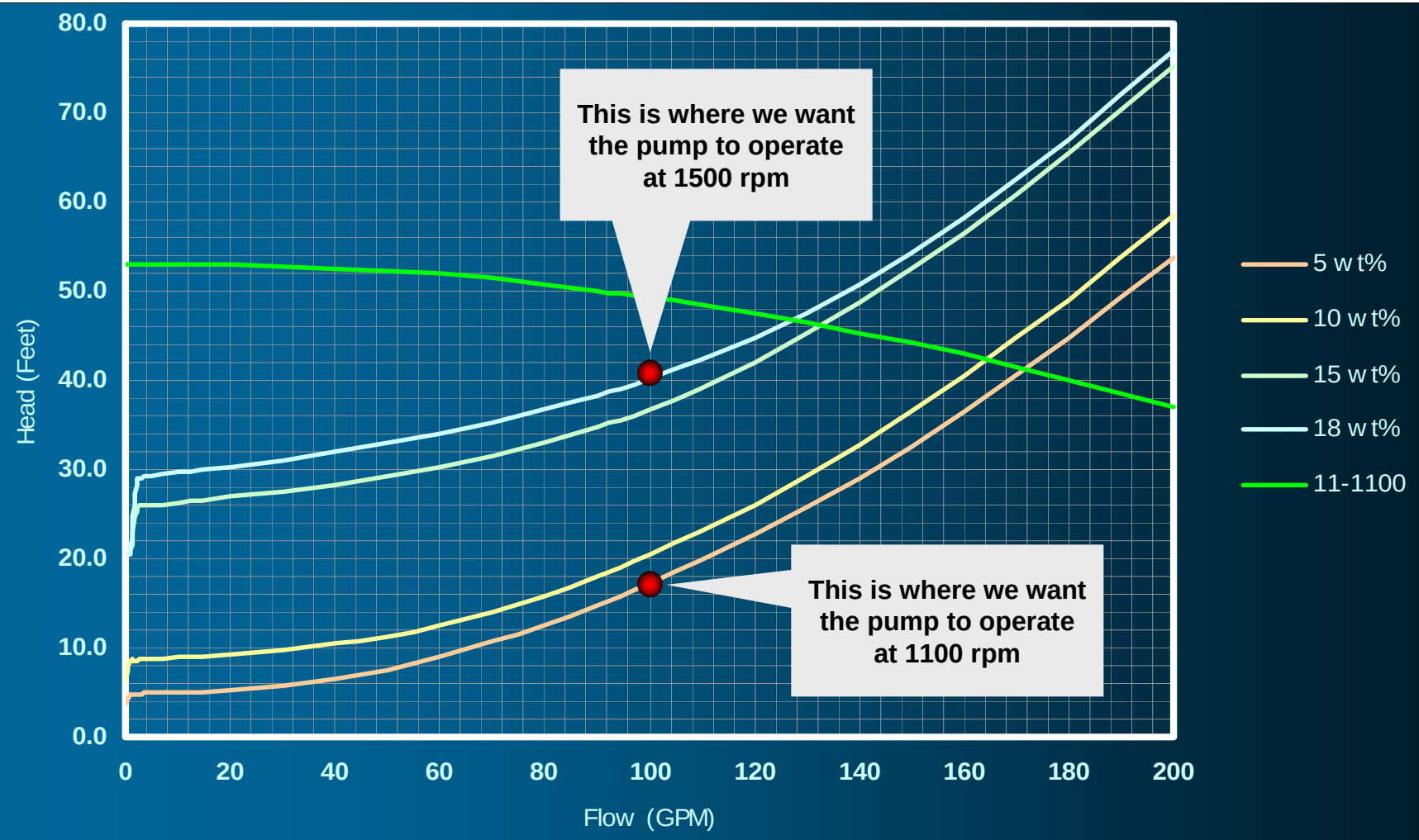
Two-K Method by Hooper

$$K = \frac{K_1}{N_{\mathrm{Re}\,BP}} + K_\infty\left[1+\frac{1}{\mathrm{ID}_{\mathrm{in}}}\right]$$

Step 3 - determine head requirements



Step 3 - determine head requirements (cont'd)



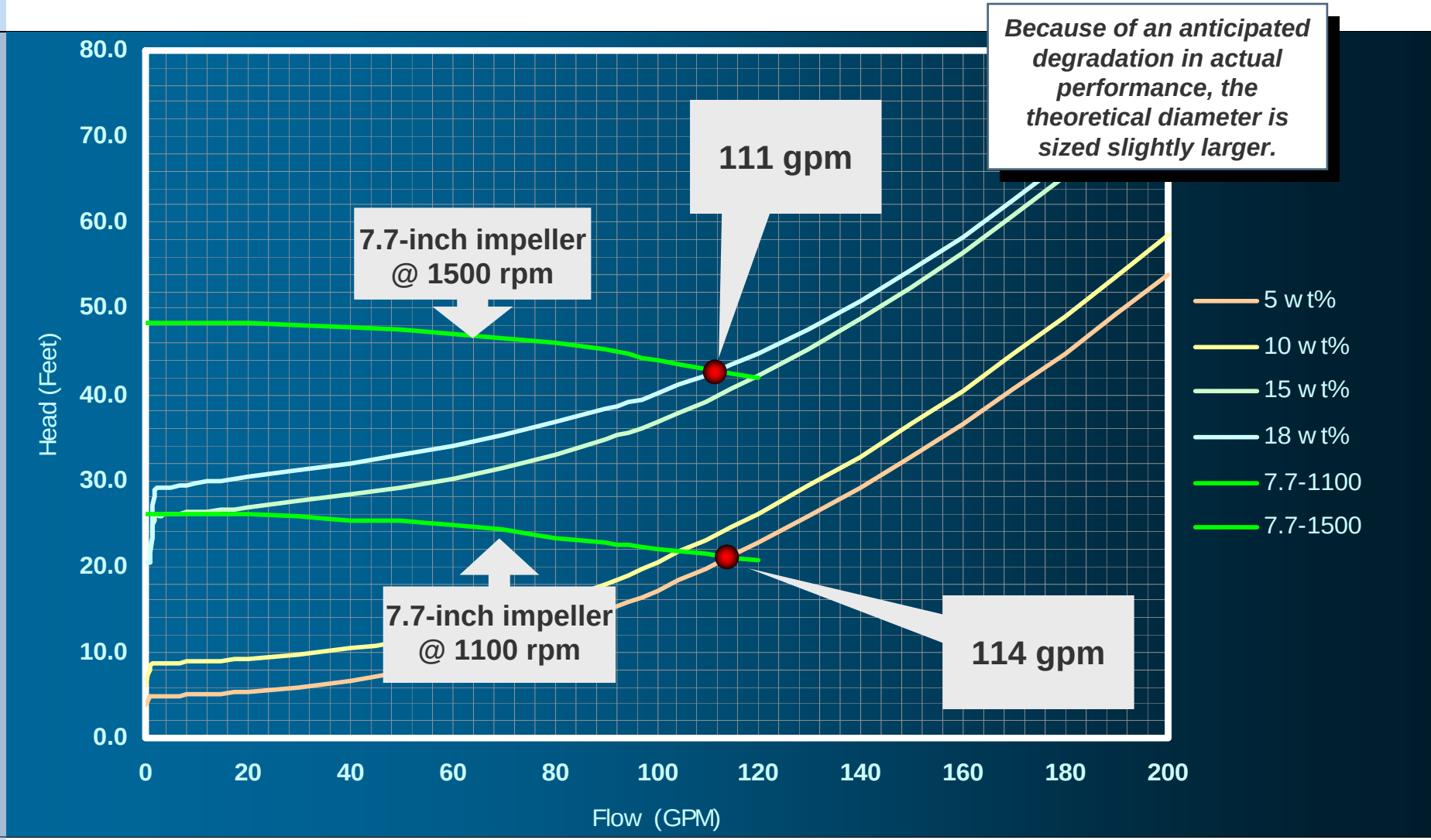
Step 4 – impeller sizing

Affinity Laws

$$\frac{S_1}{S_2} = \frac{D_1}{D_2} = \frac{Q_1}{Q_2} = \frac{\sqrt{H_1}}{\sqrt{H_2}}$$

D = impeller diameter
H = head
Q = flowrate
S = pump speed

Step 4 – impeller sizing (cont'd)



Step 5 – impeller size correction

- any diameter reduction greater than 10% will deviate from the affinity laws.
  - The head and flow will be less than predicted.
  - The degree of deviation is an educated guess.
  - Reduce diameter in stages
- desired to trim and test the impeller once.
- uncorrected diameter (7.7 inches) chosen to allow slightly higher flow and head.

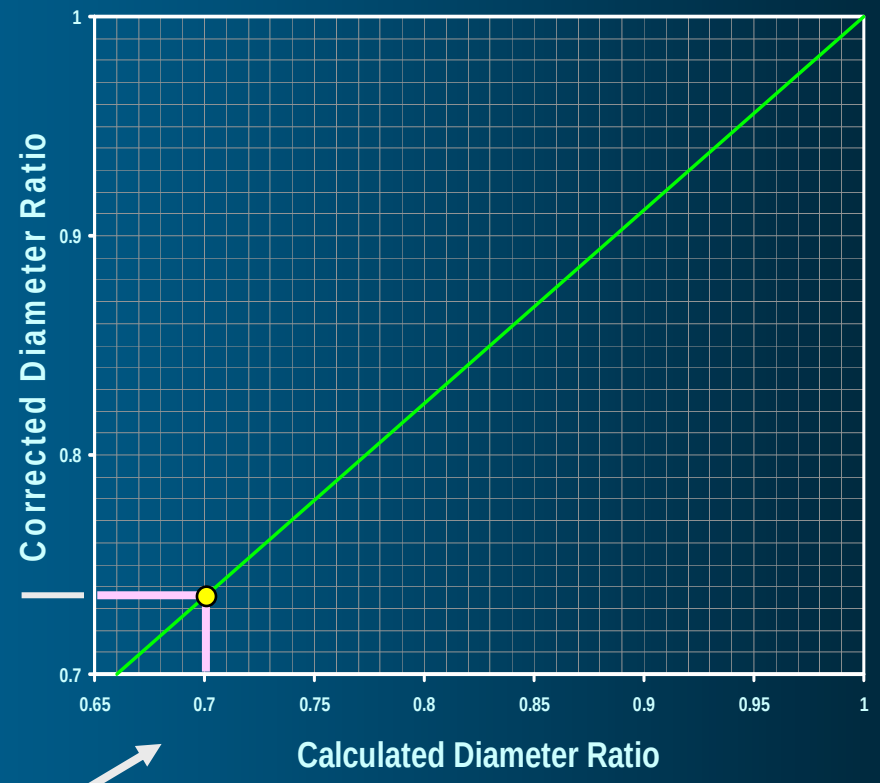
Step 5 – impeller size correction (cont'd)

- two industry proven methods to correct calculated impeller diameters:
  - Stepanoff Method
  - Rütshi Method
- both were used to provide a correction factor based on engineering judgment.

Stepanoff Method

$$D_{Corrected} = 0.735 \times 11.0''$$

$$D_{Corrected} = 8.09 \text{ inches}$$



0.735

$$\frac{D_{Calculated}}{D_{Original}} = \frac{7.7}{11.0} = 0.7$$

"Centrifugal and Axial Flow Pumps", A. J. Stepanoff, 2nd edition, 1957. Figure 5.11. Page 87. Used by Permission. John Wiley & Sons, Inc. New York, New York

Step 5 - Impeller Size Correction

Rütshi Method

$k = 0.88$

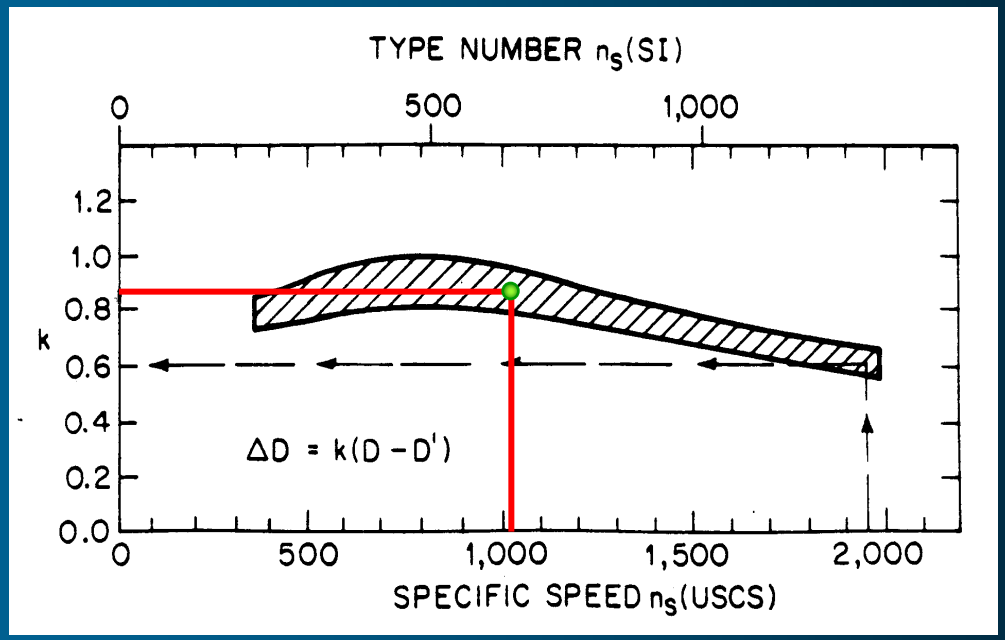
$\Delta D = k(D - D')$

$\Delta D = 0.88(11 - 7.7)$

$\Delta D = 2.90 \text{ inches}$

$D_{Corrected} = 11 - 2.90$

$D_{Corrected} = 8.10 \text{ inches}$



First determine Specific Speed

n_s Input

H = 155 ft

Q = 395 gpm

S = 2250 rpm

$$n_s = \frac{S\sqrt{Q}}{H^{0.75}} = \frac{2250\sqrt{395}}{155^{0.75}} \approx \underline{\underline{1020}}$$

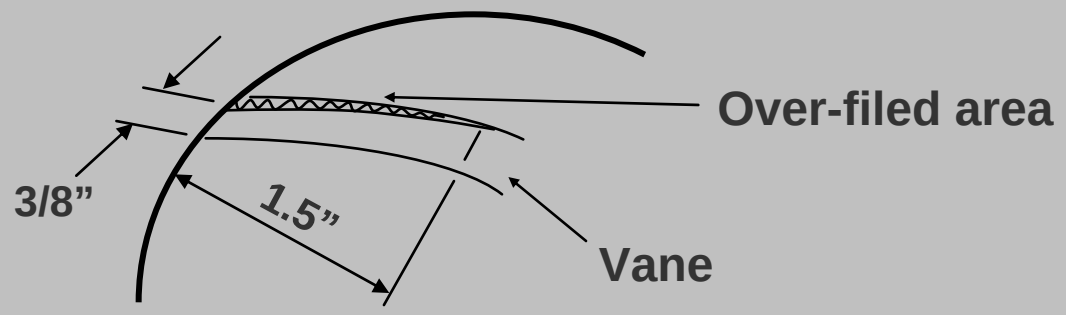
"Untersuchungen an Spiralgenhäusepumpen verschiedener Schnelläufigkeit," Schweiz. Arch. Angew. Wiss. Tech., Volume 17. No. 2. Figure 13, Page 38. February 1951. Used by permission.

Impeller Size Correction Summary

- both methods resulted in an impeller diameter of roughly 8.1 inches
- because of the concern that the pump might be oversized, the recommended size was 8.0 inches
- this would provide sufficient low-end performance without sacrificing high end characteristics

Step 6 – trim impeller

- cut vanes and shrouds to 8.0 inches
- overfile impeller vanes and blend the file 1.5 inches into vane as shown:

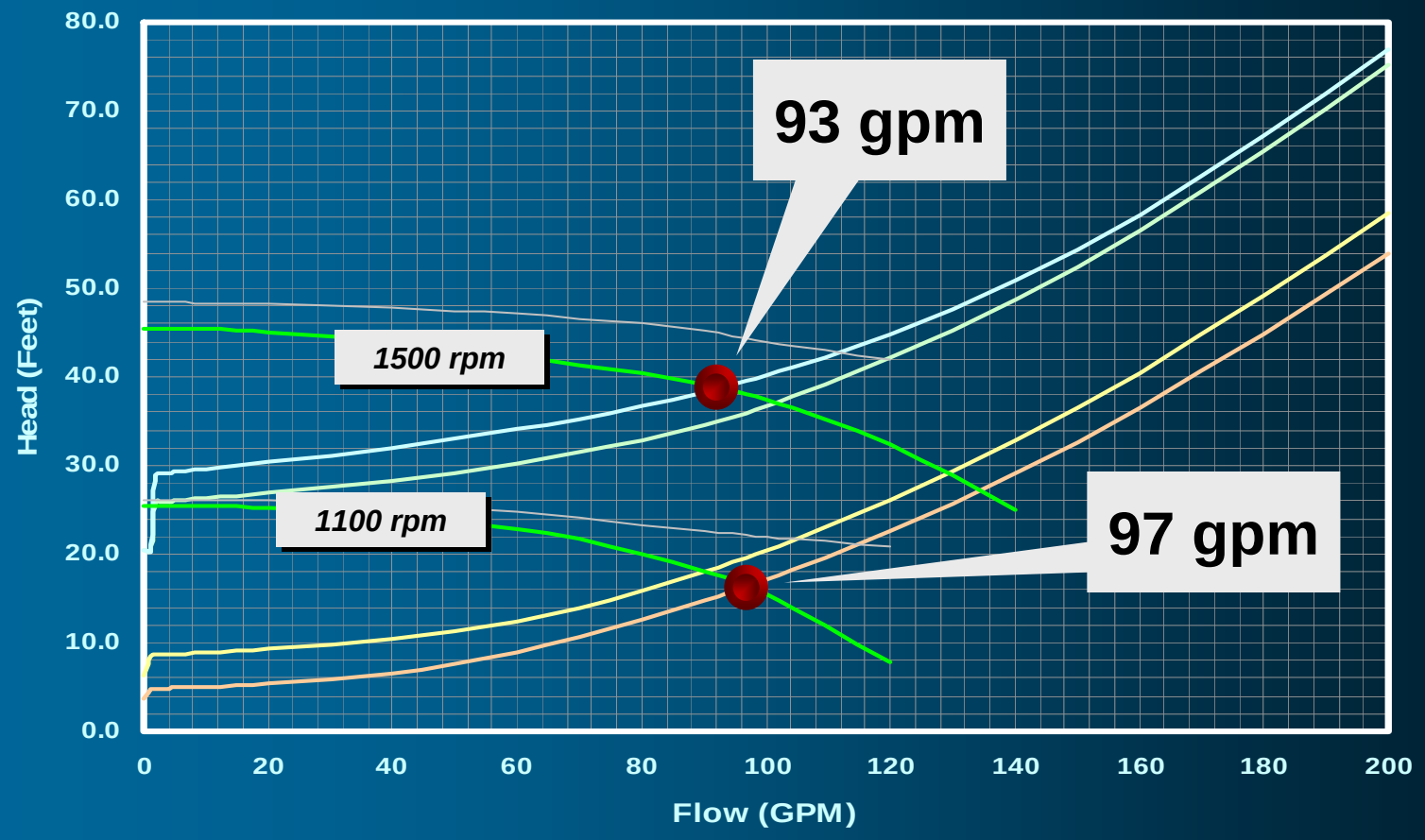


- speed balance impeller and install

Transfer pump being inserted into Tank 8

long shafted telescoping centrifugal pump suspended from crane.

Step 7 – field results



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