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COST OPTIMIZED PUMPING IN THE PHOSPHATE INDUSTRY

FINAL REPORT

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ABSTRACT

Pumping equipment and energy costs comprise a large portion of the money that is both invested and spent as operating costs in the phosphate industry. This paper offers a pro-forma cost-based computer model that optimizes up-front investment with on-going operational costs to yield a minimum life cycle cost for the owner. Purchasing the smallest pump and piping system during engineering design and construction makes the project manager a cost savings hero. Operating such a high pressure drop system over ten years results in high energy costs and frequent maintenance for the utility manager and front line mechanics. The owner is left to struggle with operating profitability and a stranded non-performing asset if forced to shut the doors. Learn how to quantify the investment, risk, and life cycle operating costs of pumping systems to optimize your company's capital costs and operating costs.

ACKNOWLEDGMENTS

I'm indebted to Bob Andrews and Francine Neuman from the American Institute of Chemical Engineers, Central Florida Section, for selecting my White Paper and giving me the opportunity to present it at the 34th Annual International Phosphate Fertilizer & Sulfuric Acid Technology Conference.

Many thanks go to Gary Albarelli, Karen Stewart, and Malysavanh Birdy of the Florida Institute of Phosphate Research who were gracious and hospitable during my five days of "camping out" in their Phosphate library.

Appreciation is extended to George Mcquien from Mosaic who provided guidance and helped me limit my topic which could have easily expanded to thesis proportions.

Much gratitude goes to Mark Thompson and Terry Tarte who in 2004 encouraged me to pursue the "hobby" of providing continuing education to professional engineers. That part-time hobby has now become my fulltime work in my new company.

INTRODUCTION

Projects that come in under budget and ahead of schedule provide great accomplishments for one's resume. However, it has been the author's experience that the "under budget" claim was accomplished with "value engineering" that focused only on a cheap bid and not true life cycle cost. Value engineering is an honorable work that involves life cycle costing and not just blind acceptance of the lowest bid. The Institute of Industrial Engineers[1] has long sought to promote corporate profitability through the proper use of value engineering, which involves cash flows through the entire life of the project for all aspects of the project. These aspects include: capital, maintenance, fuel, insurance, taxes, labor, loans, administrative overhead, marketing, transportation, etc.

When energy auditors like myself walk the plant, calculate operating cost, and develop energy saving options, it is then that we sometimes discover that capital cost was "king" during construction and that long-term maintenance and operating costs were often ignored.

Many times pipes and wires are undersized, resulting in higher pumping and electrical costs. Cooling towers were purchased based on square footage with little regard for fan horsepower and now that electricity prices are rising, operators want to shut off the "energy hog" fans but find the natural air or reduced air flow option is insufficient to reject the heat load. Chillers also were purchased based on dollars per ton of capital cost and not on kW/ton efficiency and as a result, higher electric bills are making up a larger portion of the building's operating budget spent on air conditioning. It's like buying that $89 ink jet printer only to find after printing a report that the ink cartridge has run dry. Now you must return to the store to purchase a $60 ink cartridge. That example illustrates the relationship between capital cost and operating cost.

[1] The Institute of Industrial Engineers (IIE), www.iienet2.org located in Norcross, GA, are the keepers of the Wellington Award which is given annually to that engineer who has contributed the most to the field of engineering economy. Arthur Mellen Wellington is considered the father of engineering economy and wrote "The Economic Theory of the Location of Railways," John Wiley & Sons, 1887, which many feel is the first engineering economy textbook. It is available from interlibrary loan from the University of Miami and the University of Chicago, as there are few copies in existence these days.

This paper will focus on cost optimized pipes and pumping since pump motors consume the majority of electricity in the phosphate business. All of the examples deal with water since 80% of the pumping horsepower involves water directly or as a carrier fluid for sand, clay, phosphate matrix, etc. Any fluid can be analyzed using the methods laid out below including phosphate matrix slurry[2] which will be the topic of another of what is envisioned as a series of papers on optimization. The spreadsheets developed for this analysis combine flow of fluids, engineering economics, operating cost, optimization strategies, cash flow, investment, depreciation, and corporate profitability.

[2] This paper and spreadsheet model is based on water only. Matrix is carried along in water in varying concentrations. This changes the specific gravity, viscosity, as well as other variables of importance. Incorporating those variables at this time was beyond the scope of work that could be carried out in the time permitted.

PIPES AND PRESSURE DROP

To size a pipe and pump to carry 1,000 gallons per minute (GPM) of water for a distance of 5,000 feet, an engineer might refer to any of the standard references such as:

- "System Syzer Calculator" circular slide rule;
- Crane "Flow of Fluids";
- "Cameron Hydraulic Data;" or
- any of a number of resources or computer modes that list pressure drop as a function of flow rate and inside pipe diameter. Most of these references have standard tables and charts for the condition most often encountered, which is the flow of water in clean steel pipe.

These resources all rely on work done by Darcy, Weisbach, Reynolds, Colebrook, Moody, Hazen, Williams, Stokes, Newton, ASME, U.S. Bureau of Mines, etc.

As such all of these flow references have a common set of data and a sequence of equations that include the following variables:

1. length of pipe
2. piping material
3. nominal diameter
4. pipe schedule number
5. flow rate in GPM
6. type of fluid
7. specific gravity
8. operating temperature
9. absolute roughness
10. relative roughness
11. Reynolds number
12. friction factor
13. viscosity
14. density

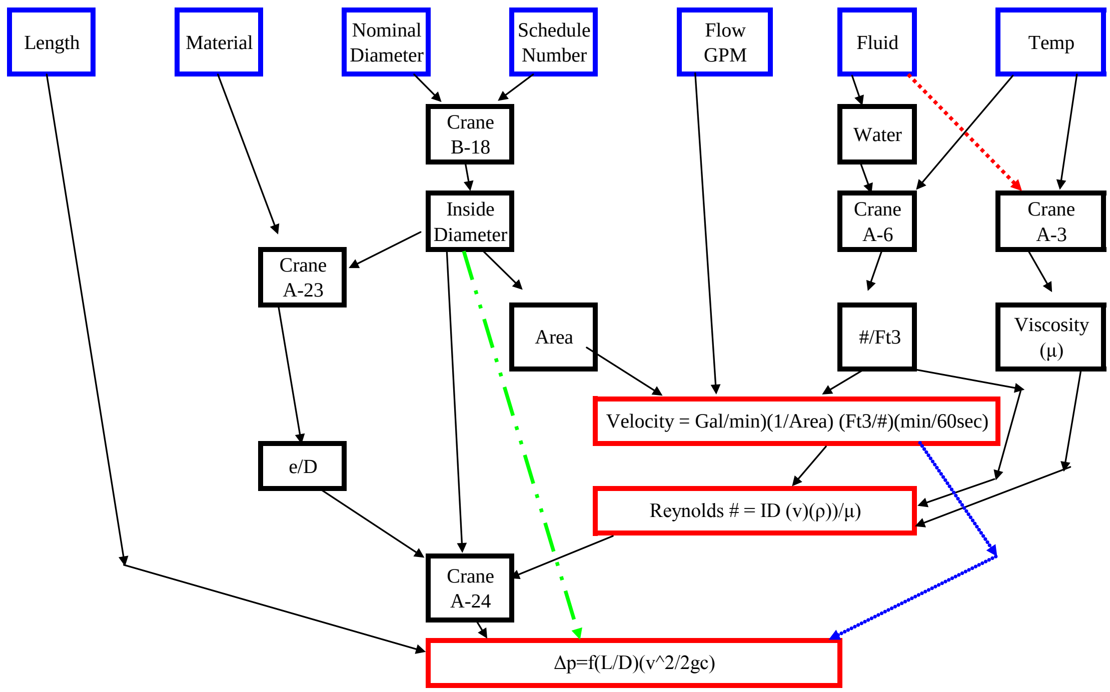
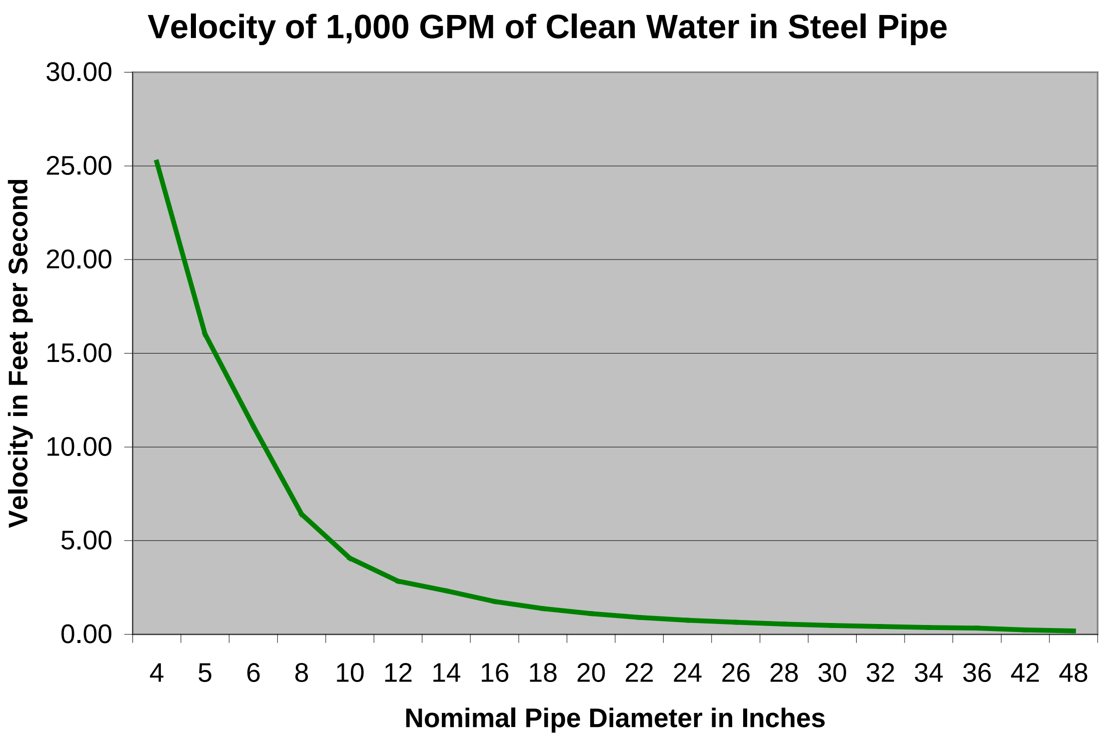


Figure 1. Flow Charting the Pressure Drop Equations

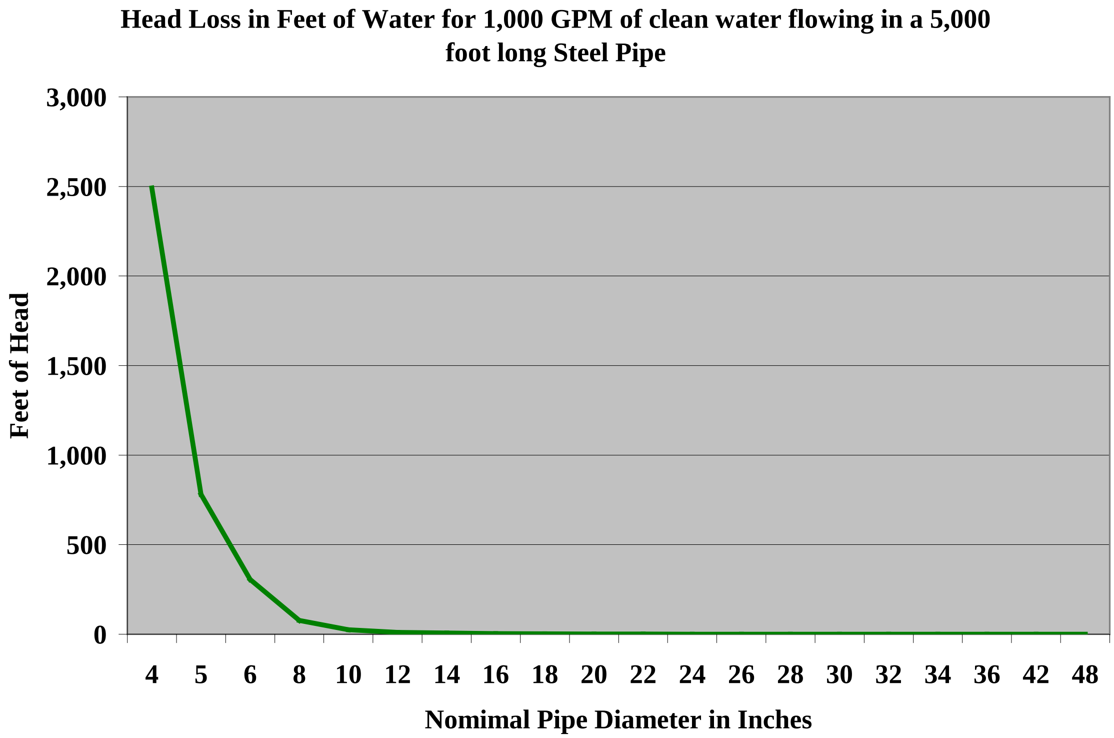
The end result of these calculations is head loss in feet of water. These variables, equations and the sequence of solution would look as appears in a flow chart representation (Figure 1) of the calculations. The blue boxes are the true variables, the black boxes are standards or table lookup values, and the red boxes are equations.

These solutions have been programmed into an Excel spreadsheet with several auto-lookup and auto-iteration features to allow faster solutions to "what if" inquiries. These have also been programmed for each pipe size from 4-inch through 48-inch which allows for easy graphing of parameters of particular interest.



Graph 1. Fluid Velocity as a Function of Pipe Diameter

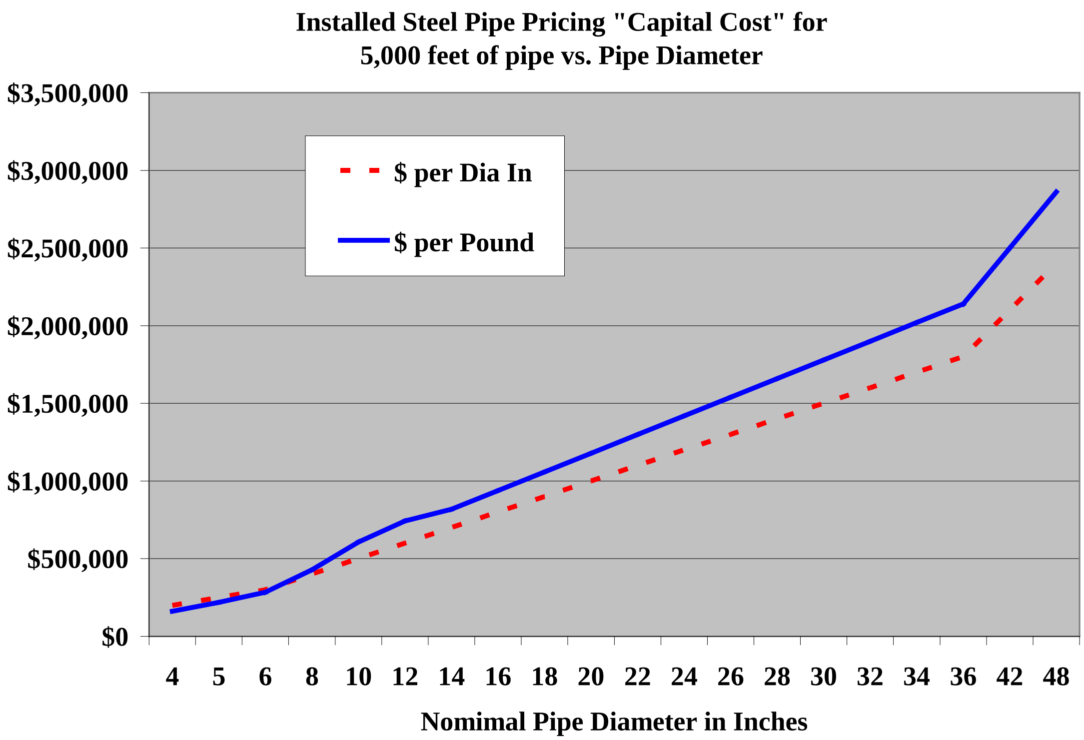
One such parameter is fluid velocity as a function of pipe diameter (as illustrated in Graph 1). For a fixed volumetric flow rate of water, velocity in feet per second drops as pipe diameter increases. Take special notice of the law of diminishing returns that results in a "knee" in the curve where a larger diameter yields only a small drop in velocity. This observation will be used over and over again for various calculations to determine the optimum pipe size.



Graph 2. Head Loss as a Function of Pipe Diameter

Another parameter of interest is head loss. This is also shown as a function of pipe diameter, as in Graph 2 above. The knee in the curve is clearly seen. Considering the scale of head loss on the vertical "y" axis one can clearly see that pump size, motor horsepower, pump purchase cost, and operating cost decrease dramatically as pipe size increases.

At this point, an engineer may have sufficient information to make a pipe diameter choice and pump / motor size and performance selection. This selection information would then be used by the cost engineer to produce a construction cost for the pipe, pump, and motor.



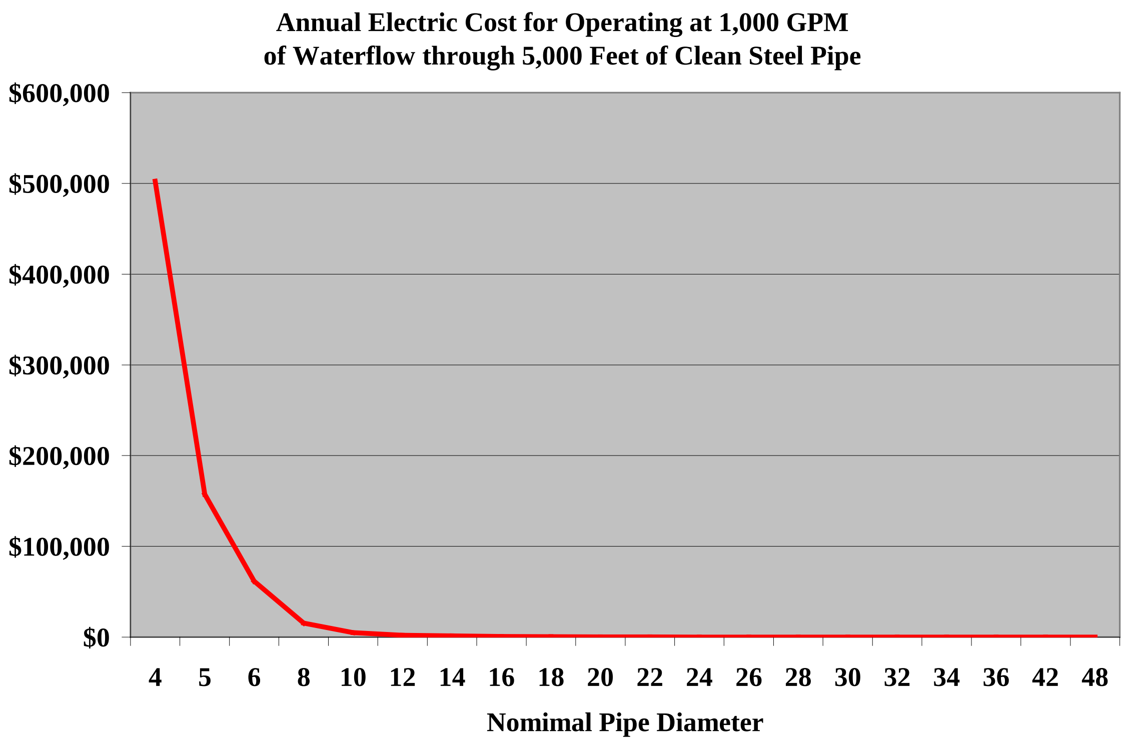
Graph 3. Installed Pipe Cost as a Function of Diameter

Graph 3 above provides an estimated installed cost for the pipe[3] based on weight or diameter as a function of pipe diameter in inches. This graph is dynamic and changes based on the length of pipe. This cost estimate is what is typically seen by the construction manager, project manager, and owner's representative. As such, they are interested in reducing cost and therefore would be focused on a smaller diameter pipe. Remember the comment "under budget and ahead of schedule" and you will appreciate the pressure they are under to reduce costs.

3 The pipe cost data comes from some work done by Henry Zhang, Jeremy D, Bartley, Weifeng Li, Howard J, Herzog, and Timothy R. Carr of the Massachusetts Institute of Technology, Kansas Geological Survey, and the University of Kansas. They presented a paper "A GIS-Based Model for CO2 Pipeline Transport and Source-Sink Matching Optimization" at the May 10, 2006 Department of Energy Technical Sessions. The full Power Point PDF of their talk can be obtained from http://www.netl.doe.gov/publications/proceedings/06/carbon-seq/Tech%20Session%20082.pdf

OPERATING COST

Many engineers would stop at this point as the traditional "mechanical" or process engineering is complete. However, an older engineering manager, working in the interest of the user, may ask how much will it cost to operate this pipe pump motor system?

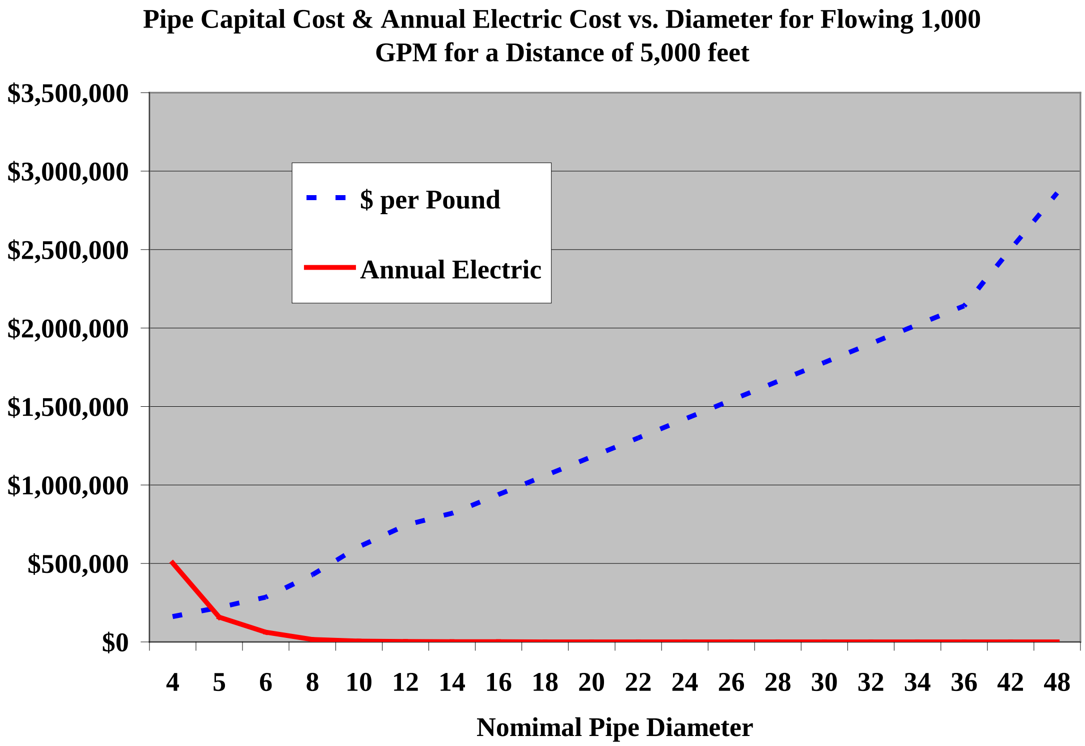


Graph 4. Annual Electricity Cost for Operating the Pump Motor

The answer to this question is based on another series of parameters that include:

- Pump efficiency;
- Motor efficiency;
- Equivalent full load operating hours; and
- the cost of electricity
  which yields a curve that looks like Graph 4.

This is the type of information an energy auditor would compute for the owner. The owner would then ask, "why didn't we build a larger diameter pipe, so the corporation could save money on the energy budget?"



Graph 5. Capital Cost of Pipe and Annual Electric Cost as a Function of Pipe Diameter

An overlay of this annual operating cost with the previous curve of capital cost would appear as Graph 5.

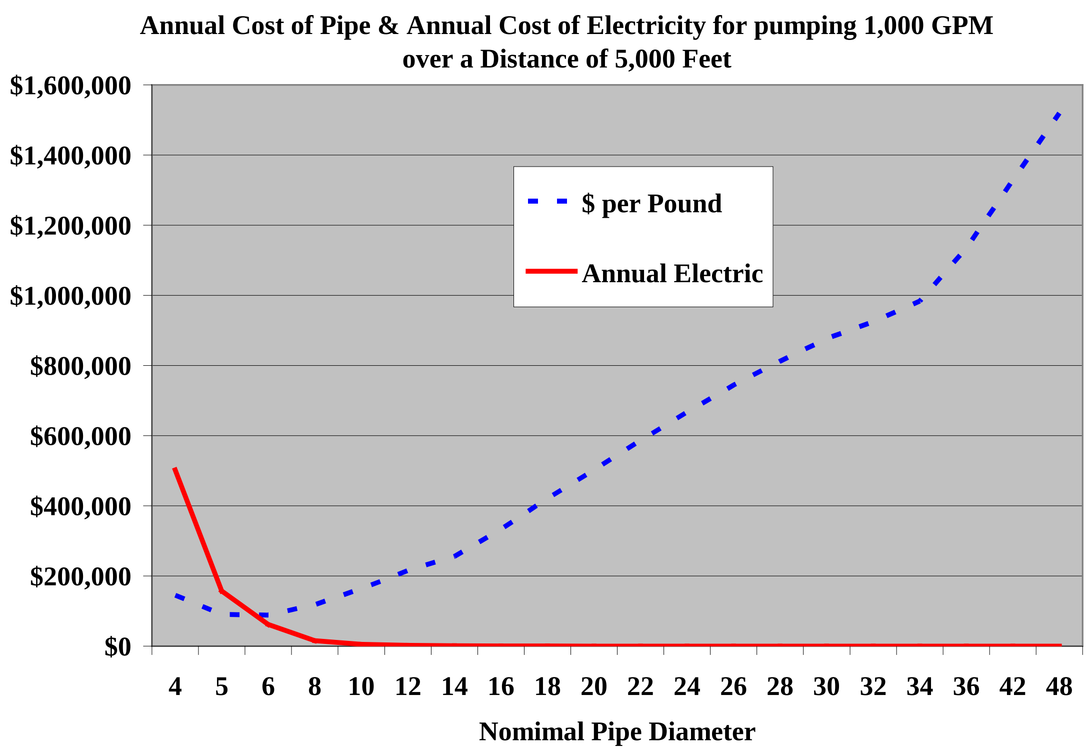
In this graphical presentation, the capital cost of the pipe dominates the dollars shown on the "y" axis and many a project manager would choose the smaller diameter, cheaper pipe. However, at this point a business person or banker might ask the question, is this a fair comparison? How can you compare a one-time capital cost with an on-going annual operating cost? Or phrased in Engineering Economy terms, how can one plot a present value (P) with an annual series (A) of values?

These are good questions and a new plot can be created as long as one considers the time value of money and assumes:

- A project life; and
- The interest rate of money.

Once again in Engineering Economy terms, we have taken the capital cost or present value (P) and converted it to an annual series (A) with the equation for the capital recovery factor (A/P, *i*, n) which asks this question:

what is **A**nnual given **P**resent at ***i***nterest rate for **n**umber of years.



Graph 6. Annual Loan Payment for Pipe and Annual Electric Cost

The answer to this question would then yield a curve that looks like Graph 6. In this graphical presentation, the capital cost of the pipe (which has been amortized over 20 years) has now taken a back seat to the more dominant annual electricity cost. A better picture of life cycle cost is beginning to emerge and the owner / operator might now think twice about "value engineering." The annual payment for energy is larger then the annual loan payment for the pipe even for pipe diameters that previously had an attractive "knee" in the curve. For an owner with a common checkbook this graph also begins to play a larger role as they ask themselves "which of these monthly checks is the largest?" Or "80% of my monthly operating and ownership cost goes towards which invoices?"

What is a common checkbook? It is the checkbook controlled by the owner / president and is used to pay all the bills regardless of the department. The author, as an engineering manager and / or project manager has been in many a meeting where departments of the same company are fighting each other over equipment choices. Construction wants the cheapest chiller. Operations wants the chiller with 10 years of free maintenance. The energy department wants the chiller that results in a utility rebate. The budget director wants the chiller that results in the lowest monthly energy payment. These fights have been intense and typically involve managers and directors up the chain of command, until finally the owner (who keeps the common checkbook) asks for a true life cycle cost. This common checkbook view also has to consider the directors, stockholders, and customers of the company's product.

This graph (Graph 6) provides a better view of this engineering / business decision and yet it is still not complete as there are additional ownership costs beyond electricity that include:

- A prediction of maintenance cost;
- Annual property tax;
- Annual insurance cost;
- Annual income tax; and
- Other costs not listed here.

These also are annual costs and need to be considered for a more complete ownership view of life cycle costing. Remember the common checkbook?

By ownership the assumption is made that the same checkbook is used to pay the construction loan, the operating labor, and the monthly electric bill. That same checkbook is also used to purchase parts and perform labor when needed. Moreover, that checkbook is also used to pay taxes, insurance and other costs associated with owning and operating the pipeline system.

This ownership assumption is necessary as sometimes the building owner installs the cheapest equipment knowing that the tenants will be directly paying the monthly electric bill and any maintenance costs out of their own personal checkbooks. In this instance the owner has no reason to consider life cycle cost.

OPTIMIZATION

At this point it should be clear that additional investment in pipe diameter results in lower operating costs. But how much extra investment is justified? An optimized system, which balances capital costs and annual costs, would be selected based on employing the concept of Incremental Investment and Incremental Return[4] (IIIR). This concept is covered in Chapter 10 of the college textbook, "Principles of Engineering Economy[5]," Eight Edition, written by Eugene L. Grant, W. Grant Ireson, and Richard S. Leavenworth[6].

In short, the incremental investment is justified ***IF*** that incremental investment (extra money for next larger size pipe) is recouped by an incremental return (extra annual energy and operational savings) that equals or exceeds the mandated corporate hurdle rate for money.

The reader is directed to Chapter 10 of the textbook for a full proof of this concept and the derivation of the minimum-cost point formula and the graphical presentation. In short, when an element of cost increases with an increase in design variables and another element of cost decreases with an increase in design variables; the stage is set for a minimum-cost point calculation.[7] The equation describing this definition looks as follows:

$$y = ax + \frac{b}{x} + c$$

Where:

- y = the total cost
- x = the variable of design
- a, b, c are coefficients for the specific problem

After some calculus and equating this to zero the following general equation is available for use in optimizing the pipeline / pump system.

$$X = \sqrt{\frac{b}{a}}$$

[4] The author has a four-hour seminar explaining this concept of incremental investment and incremental return, available at www.GEEintl.com.

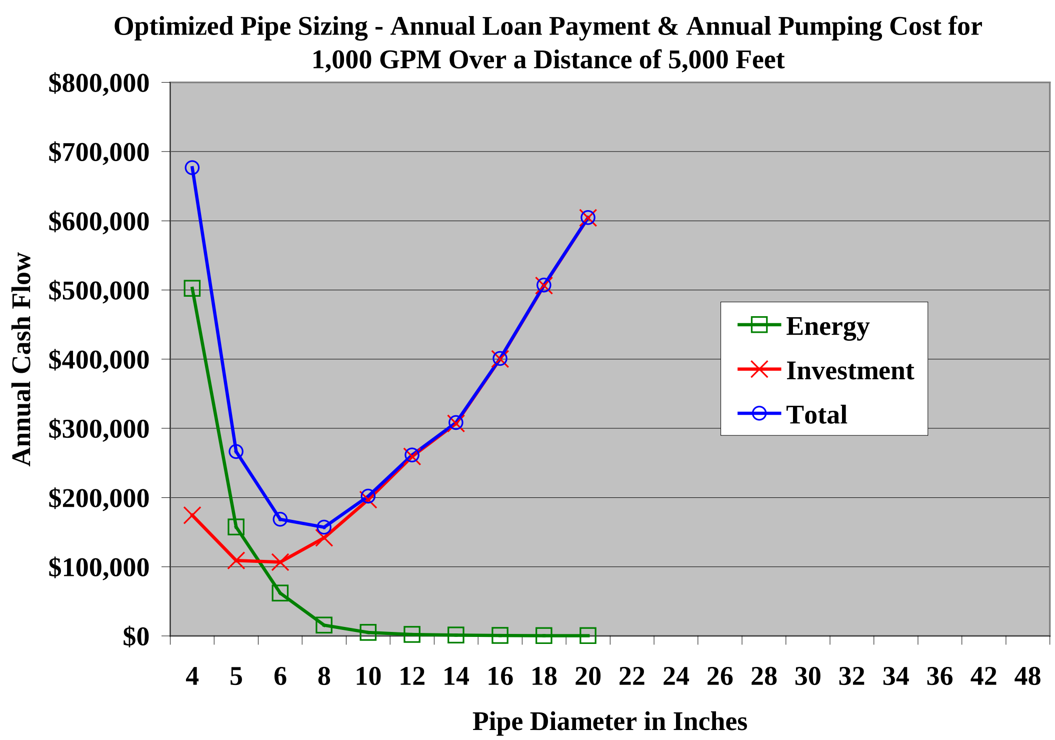
[5] The author started his professional engineer continuing education teaching career with this book and offers a four-hour seminar that provides an overview all 17 chapters of this college textbook.

[6] Each of these three authors have been the recipients of the prestigious Wellington Award. All three are now deceased. Leavenworth died last year and was a longtime professor at the University of Florida.

[7] Paraphrase of Page 225 and 226 of the referenced textbook.

Where:

- "X" is the value of the design variable which in our case is pipe diameter that results in the minimum cost.
- "b" is the first cost or capital cost for the pipe, pump, and motor converted to an annual value using an interest rate and project life.
- "a" represents all of the annual costs such as electricity, maintenance, insurance, and taxes, etc.



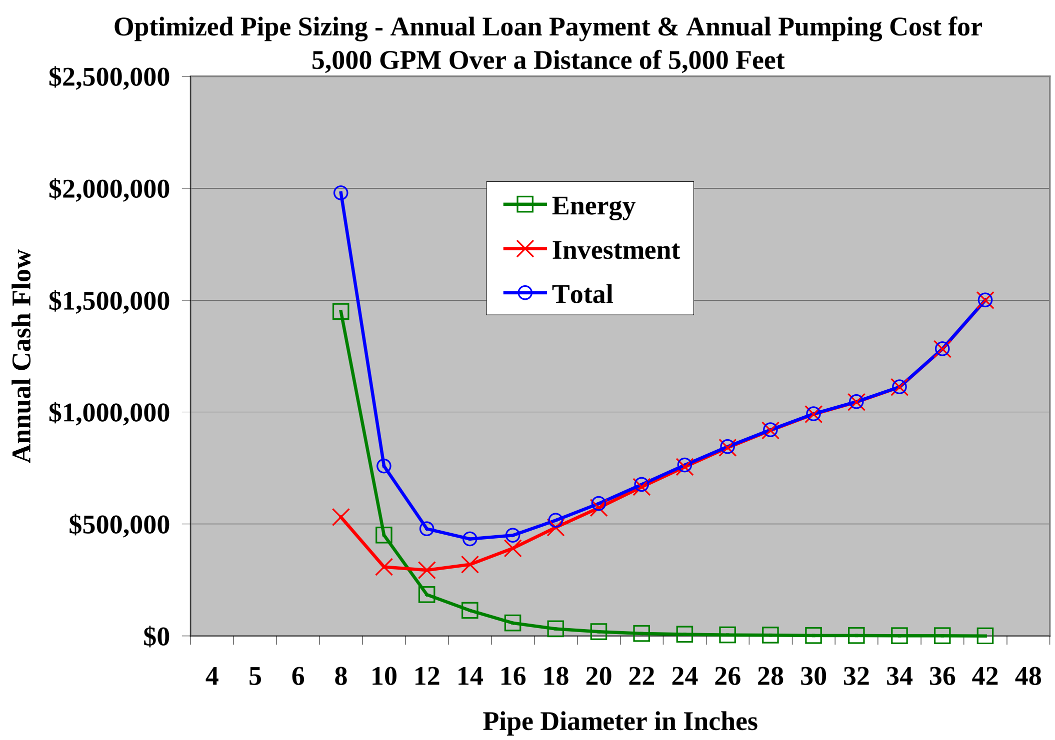
Graph 7. Optimized Pipe Pump Sizing for 1,000 GPM

Adapting this financial concept of incremental investment and incremental return, to the pipeline / pump / motor system in question results in (Graph 7) that clearly shows the minimum-cost point as 8-inch diameter pipe. The green line shows the annual electric energy costs for operating the pump against the head pressure. The red line shows the annual loan payment and other annual cost of ownership such as insurance, taxes, labor, etc for each pipe diameter displayed. The blue line is the sum of the green and red lines and shows the minimum cost point for owning and operating the entire system.

For this example and the stated conditions, the optimized pipe size is an 8-inch line. The stated conditions of particular interest are:

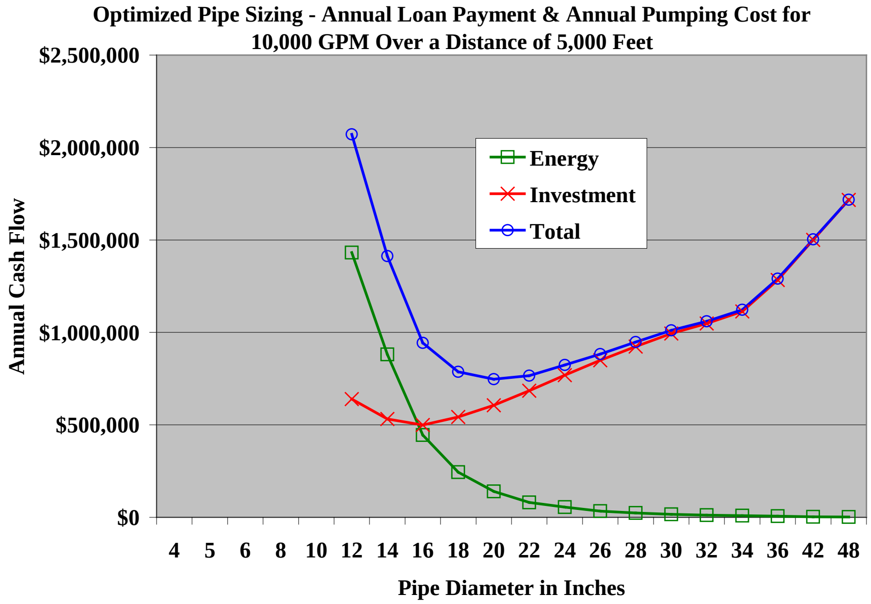
- Distance pumped = 5,000 feet
- Gallons per minute pumped = 1,000 GPM
- Pump efficiency = 80%
- Motor efficiency = 96%
- Equivalent full load operating hours = 7,280 hours
- Electricity cost of $0.12 per kWh
- Project life of 10 years
- Loan interest rate of 12%

It should be clear that changing the flow rate to ever higher amounts and keeping all the other variables constant will result in different pipe sizes as follows in Graph 8:



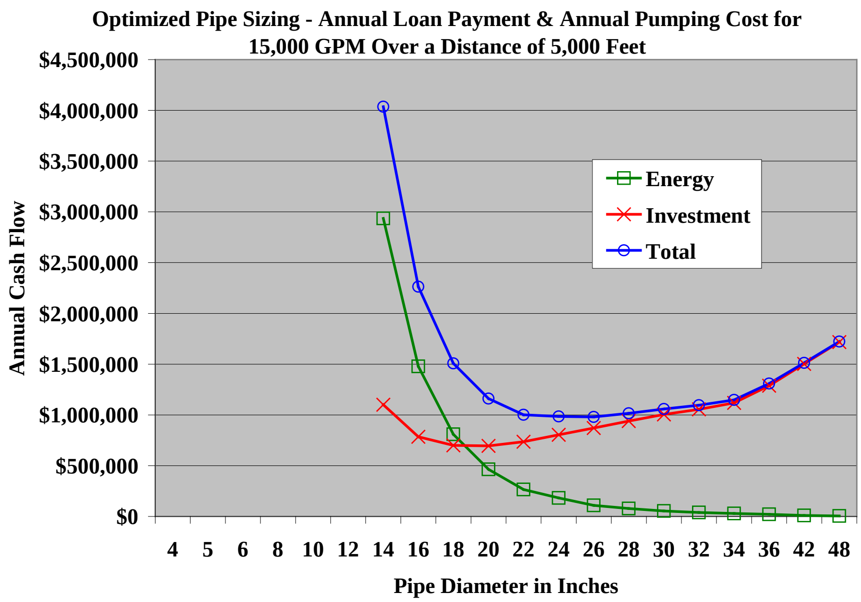
Graph 8. Optimized Pipe Pump Sizing for 5,000 GPM

Graph 8 above illustrates sizing for 5,000 GPM:



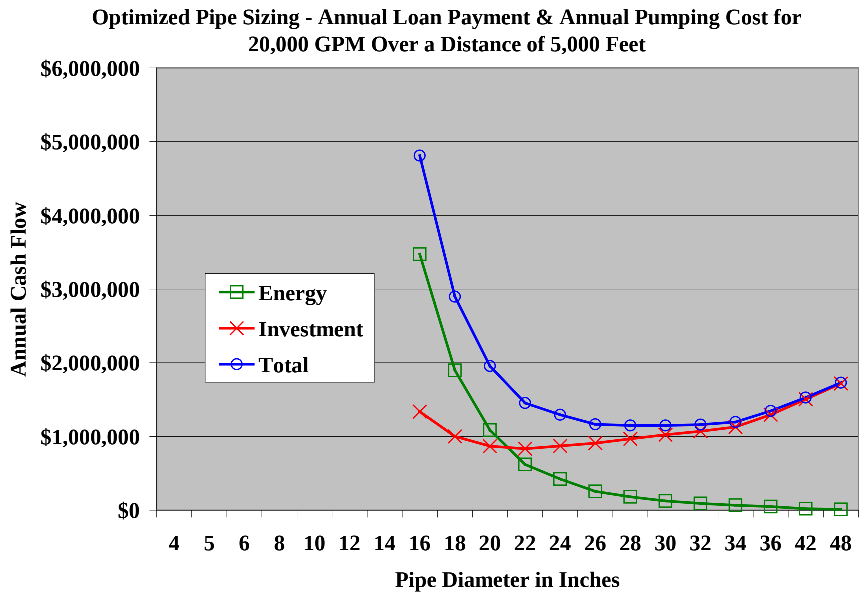
Graph 9. Optimized Pipe Pump Sizing for 10,000 GPM

Graph 9 increases the load to 10,000 GPM:



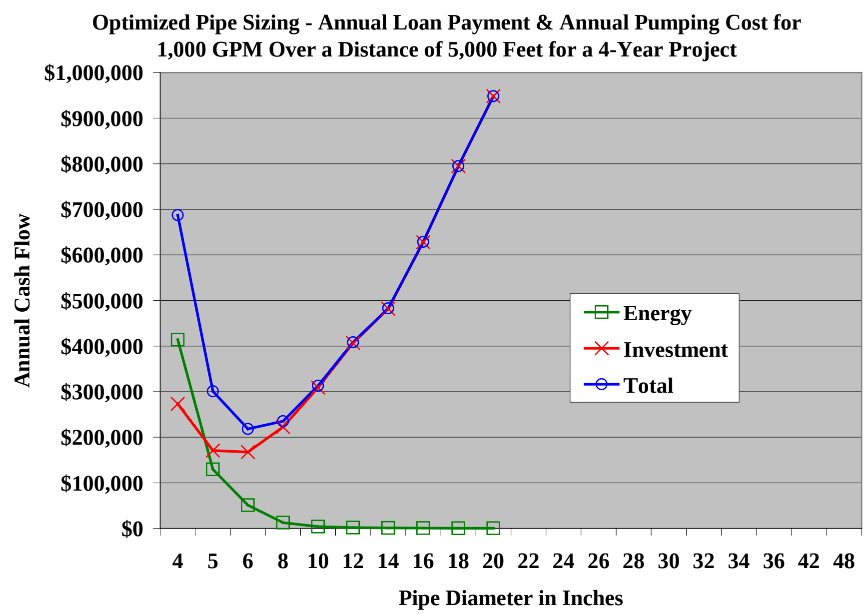
Graph 10. Optimized Pipe Pump Sizing for 15,000 GPM

Graph 10 increases it to 15,000 GPM:



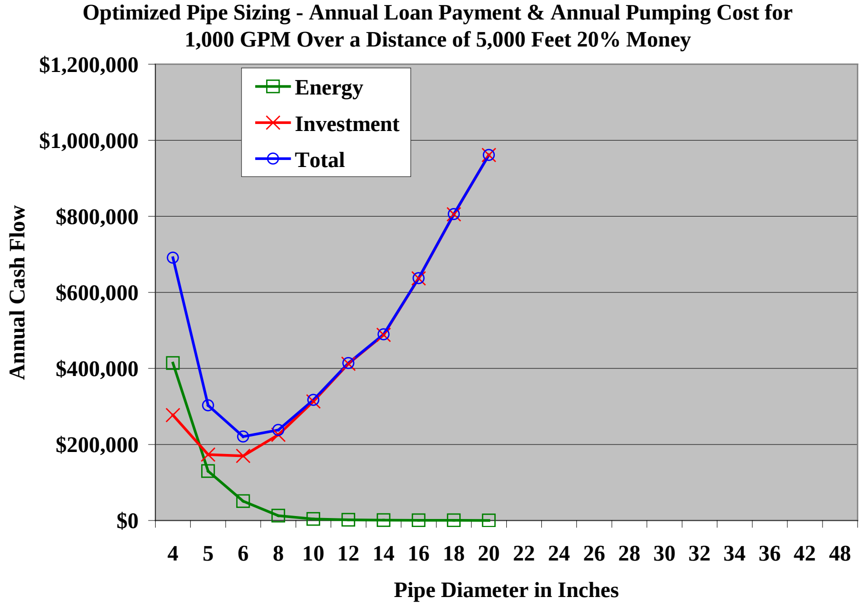
Graph 11. Optimized Pipe Pump Sizing for 20,000 GPM

Graph 11 expands it to 20,000 GPM:



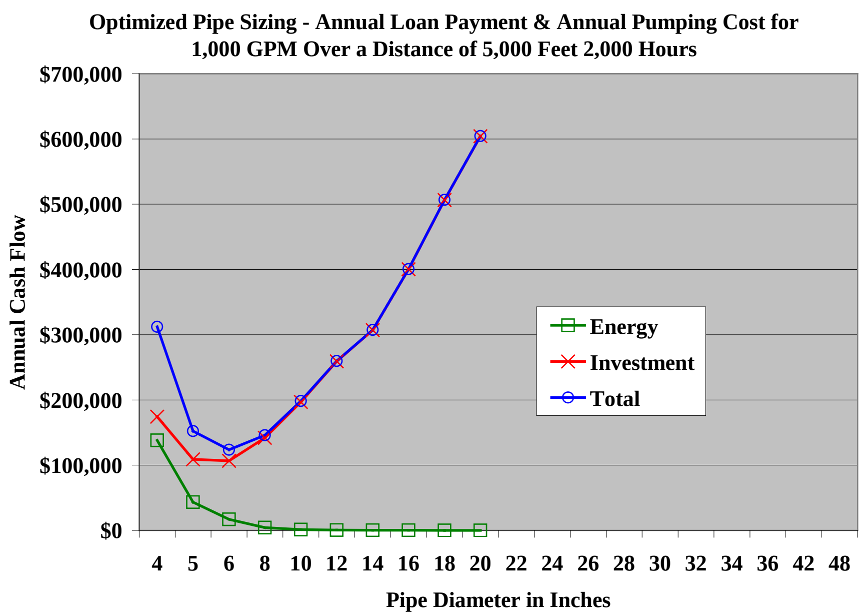
Graph 12. Optimized Pipe Pump Sizing for 1,000 GPM and 4-year Project Life

Changing the project life from 20 years to 4 years results in a smaller pipeline, as shown by Graph 12. This selection would be appropriate for a temporary line and also assumes zero salvage value. Of course if you have pipe that you move around and use in different applications then this analysis would need to be redone to consider the total long term corporate ownership and not just a specific short term project perspective.



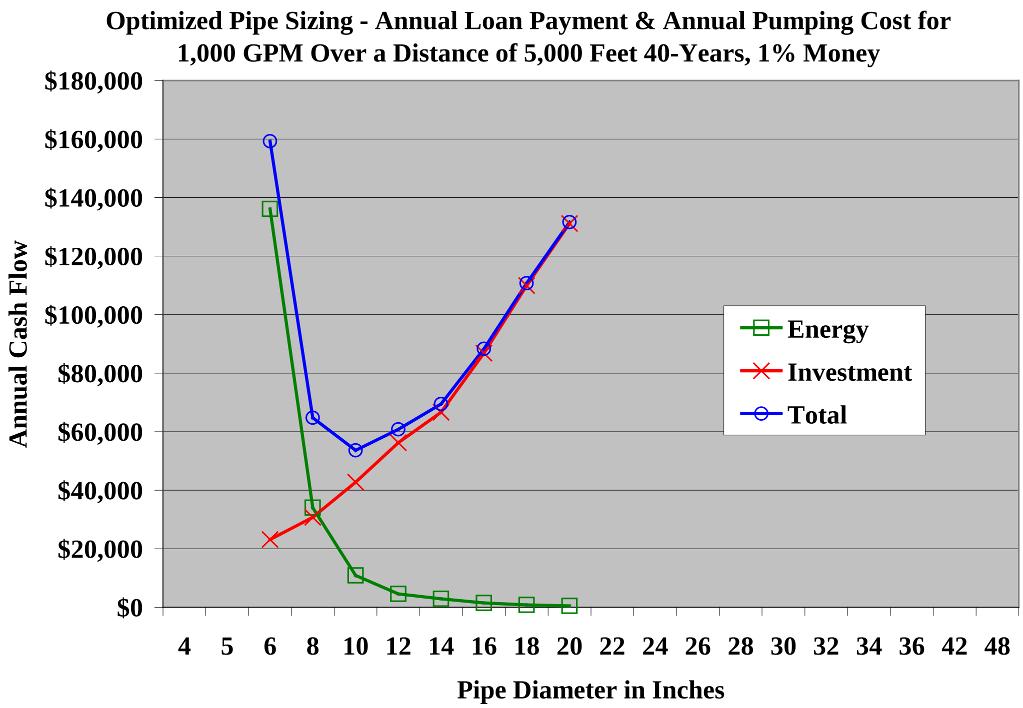
Graph 13. Optimized Pipe Pump Sizing for 1,000 GPM and an Interest Rate of 20%

Changing the interest rate from 12% to 20% also results in a smaller pipeline, seen in Graph 13. Higher interest rates indicate paying off a loan with cheaper future dollars.



Graph 14. Optimized Pipe Pump Sizing for 1,000 GPM Operating 2,000 Hours

Since we know that annual electric energy cost drives the pipe / pump selection it should come as no surprise that reduced operation such as 2,000 hours per year also results in a smaller diameter pipe as shown in Graph 14.



Graph 15. Optimized Pipe Pump Sizing for 1,000 GPM 40-Years, 1% Money

If a public utility were to size a water line for 40 years of operation and have access to low interest rate bond money or zero interest stimulus money along with a concern about increasing energy cost, then the 10 - inch pipeline of Graph 15 would be the result of the sizing program.

This is an Excel spreadsheet model that can be used to optimize a pipe / pumping system based on your own particular corporate and project requirements. Each of the listed variables and more can be adjusted. This model can also be edited (only by a very experienced Excel user) and used to account for any other special costs that are unique to your project such as cost of purchased water, cost of disposal, or taxes on water. The current model is set up for water but can also be edited for other fluids.

Comparison

Reference	Nominal Pipe Diameter											
Cameron	4	5	6	8	10	12	14	16	18	20	24	30
Crane		5	6	8	10	12	14					
System Syzer			6	8	10							
Optimum				8								

Table 1. References and Nominal Pipe Diameter

Recall that at the start of this paper several pipe sizing references were listed and here is how they compare when one looks up the recommended pipe diameter for flowing 1,000 GPM. Table 1 contains the numerical results from looking up 1,000 GPM (from each of the four references) and scanning the tables or charts for an answer.

Cameron Hydraulic Data lists flow, fluid velocity, and head loss on separate pages - one for each pipe diameter. The 1,000 GPM flow rate is listed for pipe diameters ranging from 4-inch through 30-inch. The user now has the choice of these sizes and must rely on experience, pressure drop, or velocity limits to make a selection. As we know the velocity will affect the pressure drop and pump horsepower but only an experienced user would know that. Moreover, the focus on pipe diameter may influence the user to only consider pipe cost to the exclusion of other factors.

Crane's book, The Flow of Fluids, has a quick selection table on page B-14 of the Appendix that contains water velocity and pressure drop for pipe sizes 5, 6, 8, 10, 12, and 14-inch. Once again the designer is left to their own choice as to the best or optimum diameter for a given pressure drop.

The "System Syzer Calculator" is a circular slide rule that does offer a limited "window" of options of flow rate for each pipe size selected. The answer given: 8 inch is in the center of a pie-shaped window that provides an "analog" view of flows from 700 GPM through 2,000 GPM along with friction loss in feet of head per 100 feet of pipe. By spinning the wheel, the user can see that there are only three pipe diameters that appear in the "suggestion" window. These are 6, 8, and 10 inch.

The Excel model, discussed above, recommends an 8-inch pipe as the optimum diameter for flowing 1,000 GPM over a 5,000 foot distance. This model also took into account operating cost and cost of ownership. This can be seen in cost optimized Graph 7.

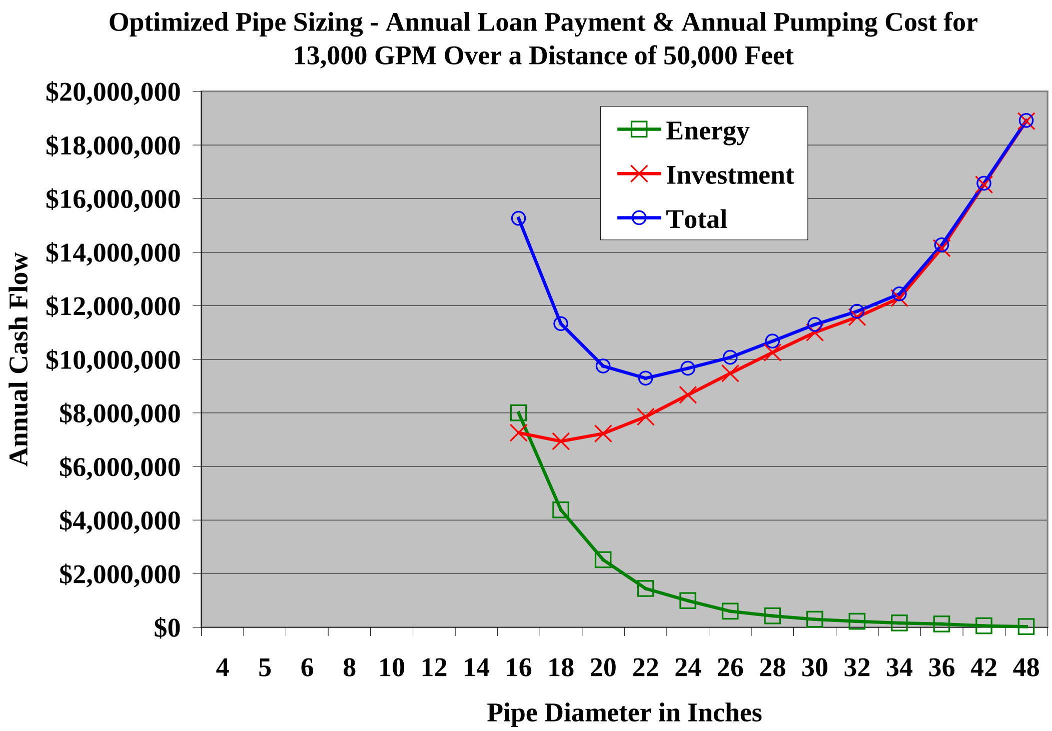
While 8 inch is the optimum diameter for our initial conditions, it is clear from the other graphs, (shown above) that the optimum diameter of pipe and pump selection is also dependent on electricity cost, hours of operation, project life, and loan interest rate. This supports the underlying principle that all capital expenditures and operating costs are only undertaken to obtain a business profit for the conditions stated.

WATER AT A SLURRY FLOW RATE AND DISTANCE

The single largest handling of water in the phosphate industry has to be the pumping of phosphate matrix from the mine to the washer plant. This delivery of matrix then results in pumping of water to carry away tailings, clays, and of course the initial source of water to the mining site. While this paper and spreadsheet model is only focused on water, we can "simulate" the effects on corporate profit by looking at a case of pumping water over a long distance.

Assume that 13,000 GPM of water must be pumped a distance of 50,000 feet. This is very common for a washer plant located in the center of a phosphate mining area that stretches around the washer plant for miles. Also assume that:

- Distance pumped = 50,000 feet
- Gallons per minute pumped = 13,000 GPM
- Pump efficiency = 80%
- Motor efficiency = 96%
- Equivalent full load operating hours = 7,280 hours
- Electricity cost of $0.07 per kWh
- Project life of 5 years
- Loan interest rate of 12%
- Maintenance is 4% of installed cost per year



Graph 16. Optimized Pipe Diameter for 13,000 GPM and 50,000 Feet Distance

Under these stated conditions, the optimum pipe size is 22 inches as shown in Graph 16 above. While 22 inches is the clear minimum cost point, both 20 and 24 inches are close to the minimum. What would the corporation's profit be under each of these three cases? Let us explore this question by getting the model data that was used to create these plotted points. Then let's look at corporate profit under three different cases involving operation expense and depreciation expense.

Energy	**$2,521,057**	**$1,424,923**	**$967,888**
Investment	**$6,572,008**	**$7,135,158**	**$7,880,407**
Total	**$9,093,065**	**$8,560,081**	**$8,848,295**
Pipe Diameter	20	22	24

Table 2. Options for the 13,000 GPM Flow Example

The color code of Table 2 is the same as that used for the lines in the graph and we can see from inspection of the table that energy costs decrease as pipe diameter increases. We can also see that investment goes up with pipe size and that the total or blue numbers are simply the summation of energy and investment. It is clear from the table that 22 inches is the minimum cost point.

SALES, EXPENSES, DEPRECIATION, TAXES, AND PROFIT

Assume that a company in the 28% tax bracket has sales in the first year that equal $21,000,000 and that sales increase at 2% per year for five years. Further assume that operating expenses equal $14,000,000 per year and hold constant over the five year period of our piping study. These simplified assumptions are arbitrary and will allow us to determine the financial impact of different pipe size options.

The engineers of the corporation are presenting three options (20, 22, and 24 - inch diameter) to management for the construction of the new 50,000 GPM pipeline which will be depreciated over five years using the straight line method. The pipeline operating expense is added to the existing expense according the values shown in Table 3, 4, and 5 below for each pipe size. Depreciation is taken as 20% of the initial investment, again according to the values listed in Table 2 and this results in the following three tables for each option.

Sales	$21,000,000	$21,420,000	$21,848,400	$22,285,368	$22,731,075
Operating Expense	$16,521,057	$16,521,057	$16,521,057	$16,521,057	$16,521,057
Gross Profit	$4,478,943	$4,898,943	$5,327,343	$5,764,311	$6,210,018
Less Depreciation	$1,314,402	$1,314,402	$1,314,402	$1,314,402	$1,314,402
Adjusted Gross Profit	$3,164,541	$3,584,541	$4,012,941	$4,449,909	$4,895,617
Taxes at 28%	$886,072	$1,003,672	$1,123,624	$1,245,975	$1,370,773
Net Profit	$2,278,470	$2,580,870	$2,889,318	$3,203,935	$3,524,844
Net Profit + Depreciation	$3,592,871	$3,895,271	$4,203,719	$4,518,336	$4,839,246

Table 3. Options for the 20 - inch Pipe / Pumping System

Table 3 represents the smaller 20 - inch line. Note that sales are increasing at 2% per year and that this is the case for all three options. The initial operating expense of $14,000,000 has been supplemented by the extra expense of the smaller pipeline. The depreciation is simply 20% of the capital cost. Depreciation is an expense that permits the corporation to recoup its capital investment through a reduction in its tax bill.

Sales	$21,000,000	$21,420,000	$21,848,400	$22,285,368	$22,731,075
Operating Expense	$15,424,923	$15,424,923	$15,424,923	$15,424,923	$15,424,923
Gross Profit	$5,575,077	$5,995,077	$6,423,477	$6,860,445	$7,306,152
Less Depreciation	$1,427,032	$1,427,032	$1,427,032	$1,427,032	$1,427,032
Adjusted Gross Profit	$4,148,045	$4,568,045	$4,996,445	$5,433,413	$5,879,121
Taxes at 28%	$1,161,453	$1,279,053	$1,399,005	$1,521,356	$1,646,154
Net Profit	$2,986,593	$3,288,993	$3,597,441	$3,912,058	$4,232,967
Net Profit + Depreciation	$4,413,624	$4,716,024	$5,024,472	$5,339,089	$5,659,998

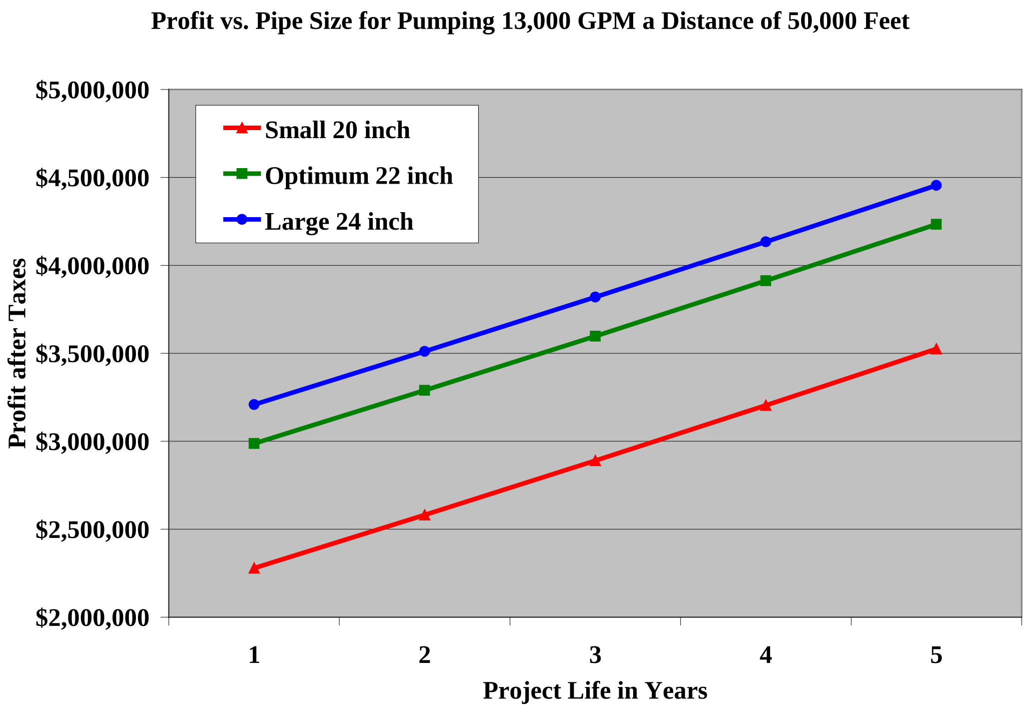
Table 4. Options for the 22 - inch Pipe / Pumping System

Table 4 is for the optimum sized 22 - inch pipeline. As an example of this cash flow math; operating expense is subtracted from sales to give gross profit. Depreciation is subtracted from gross profit to obtain adjusted gross profit. Taxes equal 28% of gross profit. Adjusted gross profit minus taxes equal net profit. Depreciation is added back to net profit to equal the money that the corporation actually gets to keep.

Sales	$21,000,000	$21,420,000	$21,848,400	$22,285,368	$22,731,075
Operating Expense	$14,967,888	$14,967,888	$14,967,888	$14,967,888	$14,967,888
Gross Profit	$6,032,112	$6,452,112	$6,880,512	$7,317,480	$7,763,187
Less Depreciation	$1,576,081	$1,576,081	$1,576,081	$1,576,081	$1,576,081
Adjusted Gross Profit	$4,456,030	$4,876,030	$5,304,430	$5,741,398	$6,187,106
Taxes at 28%	$1,247,688	$1,365,288	$1,485,240	$1,607,592	$1,732,390
Net Profit	$3,208,342	$3,510,742	$3,819,190	$4,133,807	$4,454,716
Net Profit + Depreciation	$4,784,423	$5,086,823	$5,395,271	$5,709,888	$6,030,797

Table 5. Options for the 24 - inch Pipe / Pumping System

Table 5 is for the 24 - inch line and is used to test the theory that if bigger is better then extra bigger is even better. Some might say that a larger safety factor is good but as we will see, the law of diminishing returns will diminish corporate profit. And we will learn that extra bigger is not better.



Graph 17. Pipe Diameter and Corporate Profit

Graph 17 is a plot of the corporation's profit after taxes for the five year project. The small pipeline (represented by the red line with triangles) while offering a profit has an 8% return on investment. The optimum sized line (represented by the green line with box) provides a 38% return on the capital invested. The extra large pipeline (represented by the blue line with circles) provides an even higher rate of return of 45%. HOWEVER, this is only a 7% increase over the optimum sized line and falls short of even the project loan rate of 12% much less the corporate hurdle (minimum acceptable rate of return for a capital project) rate which may be 20% or higher. Incremental investment (in the extra large pipe) does not yield an incremental investment that is attractive to the corporation. The 22-inch pipe is the optimum sized pipe and is the correct size despite the closeness of the other two to the minimum cost point of Graph 16.

SUMMARY

What began as a simple assignment to size a pipe for water flow has resulted in an impact on corporate profits. Sometimes these pipe sizing assignments are given to junior engineers with little to no knowledge of the impact on the company's bottom line. Sometimes these assignments are part of a design build contract where the focus is on cost and schedule. In recent years, budget cutbacks have resulted in cuts regardless of impact on the life cycle cost of the project or the profitability. As a result, we have witnessed rework, supplementing projects, and repurchase of sold assets. Rework because the thing engineered and constructed did not perform[8] as required. Supplementing because the pipe, process, or machine needed a smaller parallel thing to provide the required output. And repurchase where the urgent need for short term cash overruled the long term interest of the enterprise just like a pawn shop.

In the old days, these pipe sizing assignments and other engineering decisions would go through a chain of command as outlined in this paper where each level of engineering supervision and corporate management would add their experience, knowledge, perspective, and responsibility. The result was a recommendation to the president that contained value added calculations from each stop along the way. The approach outlined in this paper attempts to computerize and link all these steps together to both speed up the decision making and also to save money on manpower.

Some might call this an expert system because the knowledge and sequence are programmed such that a "what if" question can be posed by a young person and the result is suitable for presentation to the president. Others might claim that this is just a computer tool to get an answer to a specific problem. In either case it shows that engineers located out in the muddy mining field do have an enormous impact on corporate profits as seen and measured on Wall Street.

[8] John Ruskin 1810 - 1900 was an English art critic and social thinker, also remembered as a poet and artist. His essays on art and architecture were extremely influential in the Victorian and Edwardian ears. John Ruskin once said, " It is unwise to pay too much, but it is unwise to pay too little. When you pay too much, you lose a little money; that is all. When you pay too little you sometimes lose everything. Because the thing you bought was incapable of doing the thing you bought it to do. The common law of business balance prohibits paying a little and getting a lot. It cannot be done. If you deal with the lowest bidder, it is well to add something for the risk you run and if you do that you will have enough to pay for something better.

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PHOTO CREDITS

Pipeline under construction in the country on Page 7 appears compliments of www.startupblog.wordpress.com

Pump / motor / base on Page 8 is compliments of Amarinth Ltd. out of the United Kingdom (Wales) www.amarinth.com

The lineup of pumps and motors located in an industrial plant on Page 15 comes from Total Pump Solutions LTD of New Zealand
www.totalpumps.co.nz

The matrix slurry pump in a muddy field on Page 26 was taken by the author while on a field trip to a phosphate mining area.

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