

Process Equipment Cost Estimation Final Report

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Abstract

This report presents generic cost curves for several equipment types generated using ICARUS Process Evaluator. The curves give Purchased Equipment Cost as a function of a capacity variable. This work was performed to assist NETL engineers and scientists in performing rapid, order of magnitude level cost estimates or as an aid in evaluating the reasonableness of cost estimates submitted with proposed systems studies or proposals for new processes. The specific equipment types contained in this report were selected to represent a relatively comprehensive set of conventional chemical process equipment types.

Background

As part of its mission to identify and develop practical and viable processes for power production, chemicals processing, fuel processing, CO₂ capture and sequestration, and other environmental management applications, NETL engineers and scientists need to both perform order of magnitude cost estimates and evaluate and assess cost estimates contained in proposals for novel processes. In these applications where process and technological specifics are lacking, detailed cost estimates are not justified. Rather, rough estimates that can be obtained relatively quickly are more suitable. There are a number of tools available to NETL engineers to assist in the performance and evaluation of chemical process equipment cost estimates.

One such tool is ICARUS Process Evaluator (IPE). IPE is a sophisticated and industry-accepted software tool for generating cost estimates, process facility designs, and engineering and construction schedules. The IPE equipment library contains over 320 process equipment types. Sizing is performed using common engineering methodologies from intrinsic sizing algorithms. IPE utilizes self-contained equipment, piping, instrumentation, electrical, civil, steel, insulation, and paint sizing and design algorithms for a preliminary equipment model that is properly integrated and evaluated for many safety and operability issues.

When used with appropriate values for the adjustable design and construction parameters, IPE provides a highly detailed and accurate cost estimate. However, the program is very complex and both expensive and time consuming to learn and use. Furthermore, IPE requires well-defined process configuration and process parameters that typical proposals do not provide. In general, it is not practical or cost-effective to use IPE for the assessment of cost estimates contained in proposals for novel processes or in generating rough cost estimates from laboratory scale data. Instead, the factored estimation methodology, a cost-effective methodology widely used in industry, is more suitable for that application. To leverage the cost information contained within IPE, a series of cost curves for different equipment types were generated. The cost curves and other information contained in this report can then be used to develop the overall process plant capital cost using the factored estimation methodology.

Results and Usage

For this activity, a general file was created in ICARUS Process Evaluator version 5.0 that contained several pieces of stand-alone equipment. The specific equipment types were selected by NETL and intended to represent a relatively comprehensive set of conventional chemical process equipment types that might be encountered in processes relevant to CO₂ capture and sequestration. Each piece of equipment was then varied in size to generate costs for a spectrum of sizes. The cost versus sizing capacity was plotted for each equipment type. The data was then regressed to provide smoothed cost curves.

The cost curves for the 31 different types of equipment examined in this report are shown on pages 6 - 40. In addition to the graphs, the applicable design specifications and equipment descriptions are provided as appropriate.

All graphs portray purchased equipment cost data. This total material cost includes:

- Internals, shells, nozzles, manholes, covers, etc as noted for each piece equipment.
- Vendor engineering, shop drawings shop testing, certification.
- Shop fabrication labor (and field labor if field-fabricated).
- Typical manuals, small tools, accessories.
- Packaging for shipment by land.
- FOB Vendor.

The total material cost does not include:

- Owner/contractor indirects (engineering, shop inspection, start-up/commissioning).
- Packaging for overseas/air shipment, modularization.
- Freight, insurance, taxes/duties
- Field setting costs (off-loading, storage, transportation, setting, testing)
- Installation bulks

The total capital cost of each piece of equipment includes material and labor charges. The material charges include the delivered equipment costs and installation bulk material costs. The labor charges include labor for handling and placing bare equipment and labor for installation of bulk materials.

Installation bulks consist of foundations, structural steel, buildings, insulation, instruments, electrical, piping, painting and miscellaneous. Tables 2 - 5 list distributive percentage factors that can be used to estimate installation bulk labor and materials for different plant types.¹ The factors vary depending on the type of process and the temperature and pressure of the system. The bare equipment cost is used as the base to apply the percentage factor for the installation material cost. This installation material cost is then used as the base to apply the percentage factor for determining the associated labor cost involved.

Handling and placing equipment involves unloading, uncrating, mechanical connection, alignment, storage, inspection, and other factors. The costs vary by type and size of

¹ AACE Recommended Practices and Standards – “Conducting Technical and Economic Evaluations in the Process and Utility Industries,” adopted November 1990.

equipment. The setting costs can be estimated by using historical work hours or by applying factors for labor cost as a percentage of delivered equipment cost. Table 6 shows approximate factors for setting various types of equipment.¹

The total cost for installing a piece of equipment would be the bare equipment cost plus the setting labor cost plus the installation bulks material and labor costs as determined from the distributive labor percentages. See Appendix A for a detailed example.

Appendix B shows the ICARUS generated purchased/ installed costs of the equipment used in each chart. All costs in this document are reported in first quarter 1998 dollars.

Assessment

The charts can be used for preliminary purchased equipment cost estimates (i.e. order of magnitude estimates with accuracy of +50%/-30% and budget estimates with accuracy of +30%/-15%). Clearly, the charts are most accurate when used for the operating conditions listed as defaults for each equipment type. Nevertheless, they should provide reasonable cost estimates for conditions that contain small or moderate deviations from the assumed design conditions. Correlations to correct for deviations in some design variables, particularly pressure, are available in the literature. Peters and Timmerhaus "Plant Design and Economics for Chemical Engineers" is one such source for correction factor data. Without appropriate correction, estimates generated for conditions that deviate markedly from those used in this study should be used with caution.

Another limitation is that most of the charts give estimates for equipment manufactured from carbon steel. Conversion factors for converting the carbon steel costs to equivalent alloy costs for a few items of equipment are shown in Table 7.²

As mentioned previously, setting costs can be estimated by using historical data or by applying factors. It should be noted that the factors do not work well for very large pieces of equipment. If available, historical work hours provide more accurate costs.

Conclusions/Recommendations

This report contains cost curves for various equipment types at specific operating temperatures and pressures. These conditions and other design parameters are listed for each equipment type. When used within the expected design conditions, the cost estimates derived from the cost curves contained in this report will provide accurate estimates. The data can also be used to provide reasonableness estimates when the actual design conditions are outside the expected values but the level of accuracy cannot be quantified.

² Perry, Robert H. , and Don W. Green, "Perry's Chemical Engineers' Handbook," The McGraw-Hill Companies, Inc., 1999.

To help quantify the error induced by large deviations in the design conditions, it is recommended that a first-order sensitivity analysis of the cost curves be performed. Another activity that could improve the range of accuracy of the charts would be to run cases with various materials of construction to show how the price is affected. If requested, additional support can be provided to expand the set of equipment types beyond those examined in this report. For example, cost data for slurry pumps and solids conveying equipment would be useful for many of the technologies at NETL.

Cost Curves

Vertical Vessel

Description: The vertical process vessel is erected in the vertical position. They are cylindrical in shape with each end capped by a domed cover called a head. The length to diameter ratio of a vertical vessel is typically 3 to 1. Vertical tanks include: process, storage applications liquid, gas, solid processing and storage; pressure/vacuum code design for process and certain storage vessel types; includes heads, single wall, saddles, lugs, nozzles, manholes, legs or skirt, base ring, davits where applicable.

Design Basis:

1st Quarter 1998 Dollars

Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

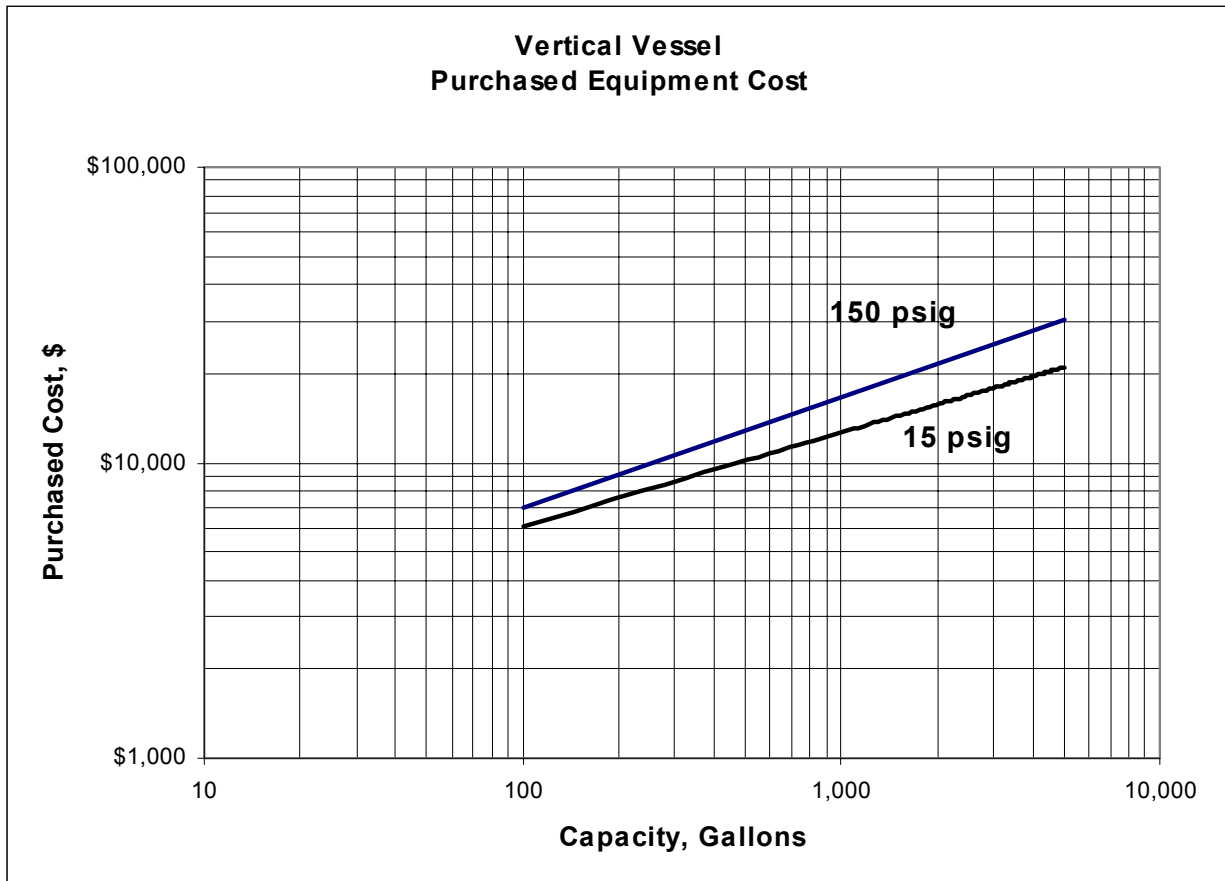
Design Temperature: 650 °F

Design Pressure: 15 psig and 150 psig

Diameter: 2.5 – 8 feet

Length: 2.7 – 13.3 feet

Total Weight: 1,000 – 7,100 pounds



Horizontal Vessel

Description: The horizontal vessel is a pressure vessel fabricated according to the rules of the specified code and erected in the horizontal position. Although the horizontal vessel may be supported by lugs in an open steel structure, the more usual arrangement is for the vessel to be erected at grade and supported by a pair of saddles. Cylindrical, pressure/vacuum, code design and construction, includes head, single wall (base material, clad/lined), saddles/lugs, nozzles and manholes.

Design Basis:

1st Quarter 1998 Dollars

Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

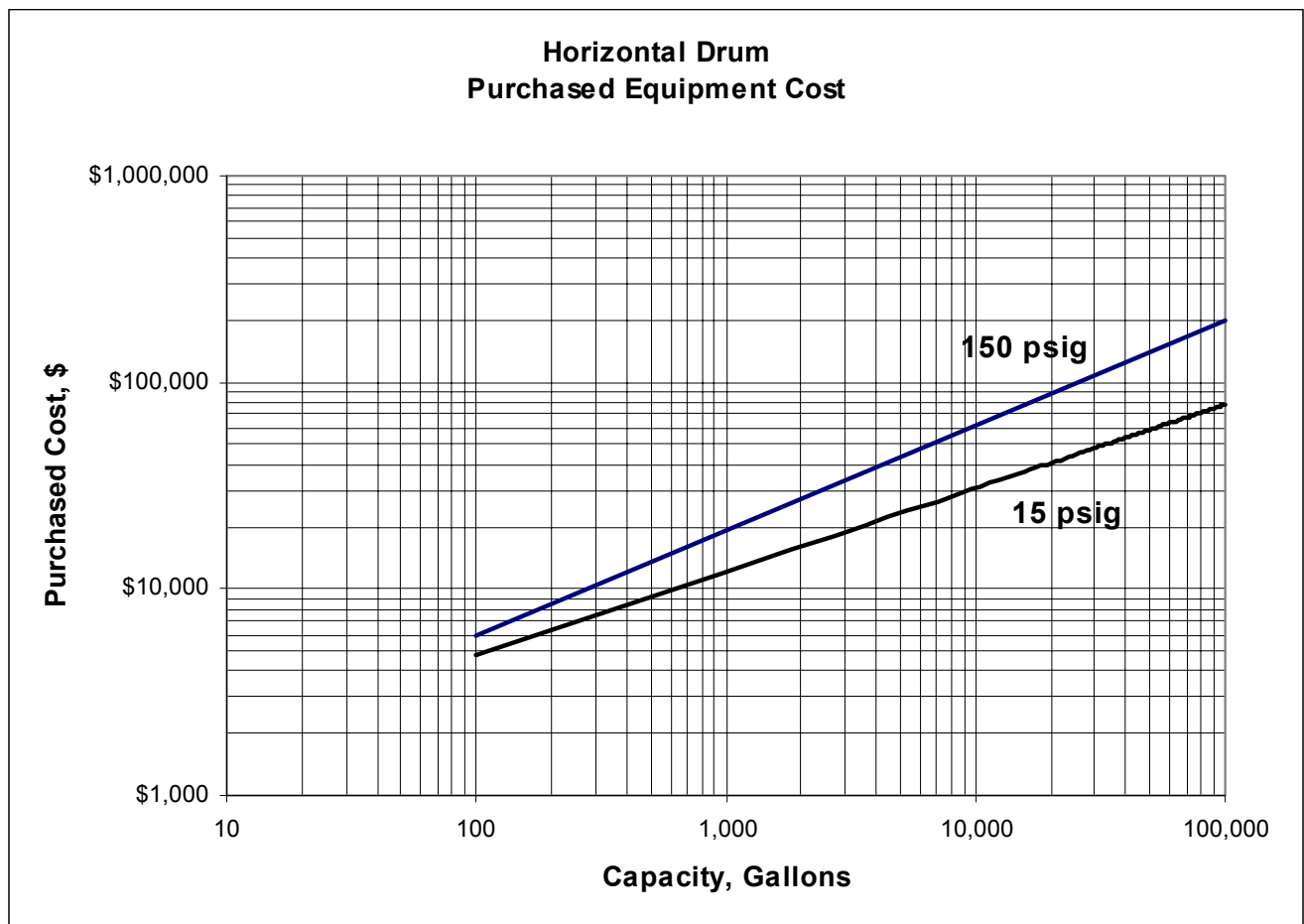
Design Temperature: 650 °F

Design Pressure: 15 psig

Diameter: 2 – 14 feet

Length: 4.3 – 81 feet

Total Weight: 1100 – 59,400 pounds



Storage Tanks

Description:

Floating Roof: Typically constructed from polyurethane foam blocks or nylon cloth impregnated with rubber or plastic, floating roofs are designed to completely contact the surface of the storage products and thereby eliminate the vapor space between the product level and the fixed roof. Floating roof tanks are suitable for storage of products having vapor pressure from 2 to 15 psia.

Cone Roof: Typically field fabricated out of carbon steel. They are used for storage of low vapor pressure (less than 2 psia) products, typically ranging from 50,000 – 1,000,000 gallons.

Design Basis:

1st Quarter 1998 Dollars

Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

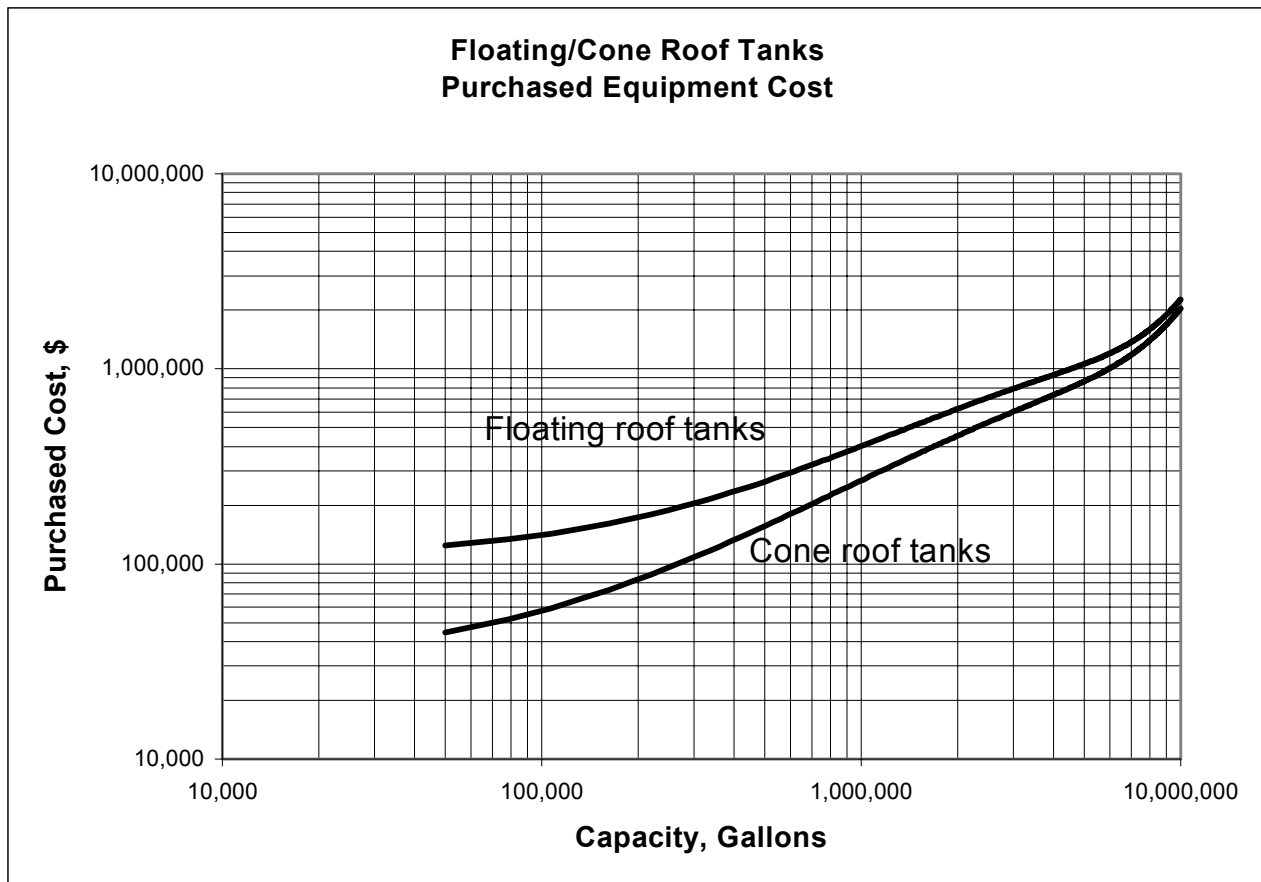
Design Temperature: 650 °F

Design Pressure: 15 psig

Diameter: 2 – 14 feet

Length: 4.3 – 81 feet

Total Weight: 1100 – 59,400 pounds



Valve Tray Column – 15 psig

Description: Pressure/vacuum column includes vessel shell, heads, single base material (lined or clad, nozzles, manholes (one manhole below and above tray stack or packed section and one manhole every tenth tray or 25 feet of packed height), jacket and nozzles for heating or cooling medium, base ring, lugs, skirt or legs; tray clips, tray supports (if designated), distributor piping, plates.

Design Basis:

1st Quarter 1998 Dollars

Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

Design Temperature: 650 °F

Design Pressure: 15 psig

Height: 17 - 133 feet

Application: Distillation

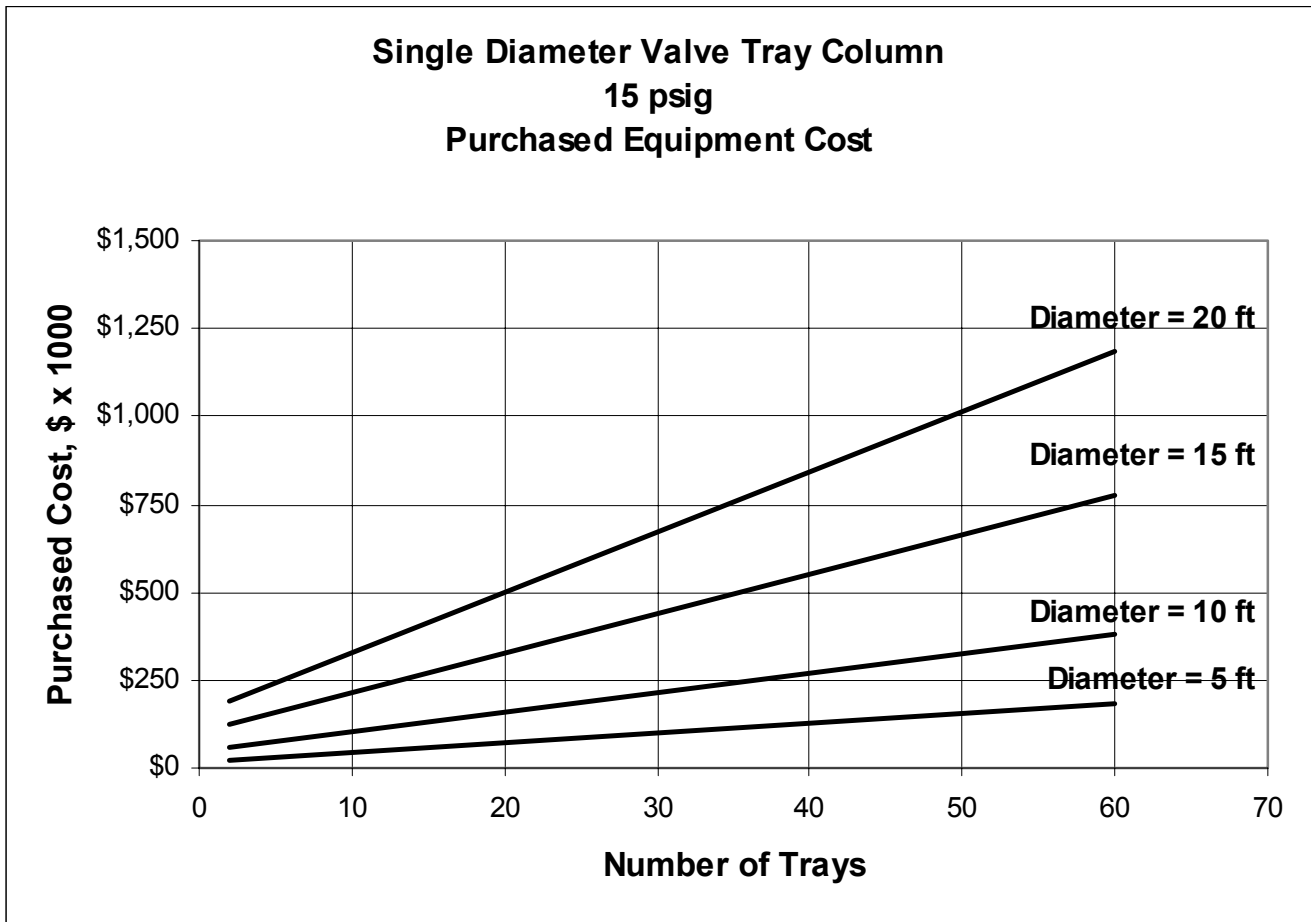
Tray Type: Valve

Tray Spacing: 24 Inches

Tray Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)

Tray Thickness: 0.19 Inches



Valve Tray Column – 150 psig

Description: Pressure/vacuum column includes vessel shell, heads, single base material (lined or clad, nozzles, manholes (one manhole below and above tray stack or packed section and one manhole every tenth tray or 25 feet of packed height), jacket and nozzles for heating or cooling medium, base ring, lugs, skirt or legs; tray clips, tray supports (if designated), distributor piping, plates.

Design Basis:

1st Quarter 1998 Dollars

Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

Design Temperature: 650 °F

Design Pressure: 150 psig

Height: 17 - 133 feet

Application: Distillation

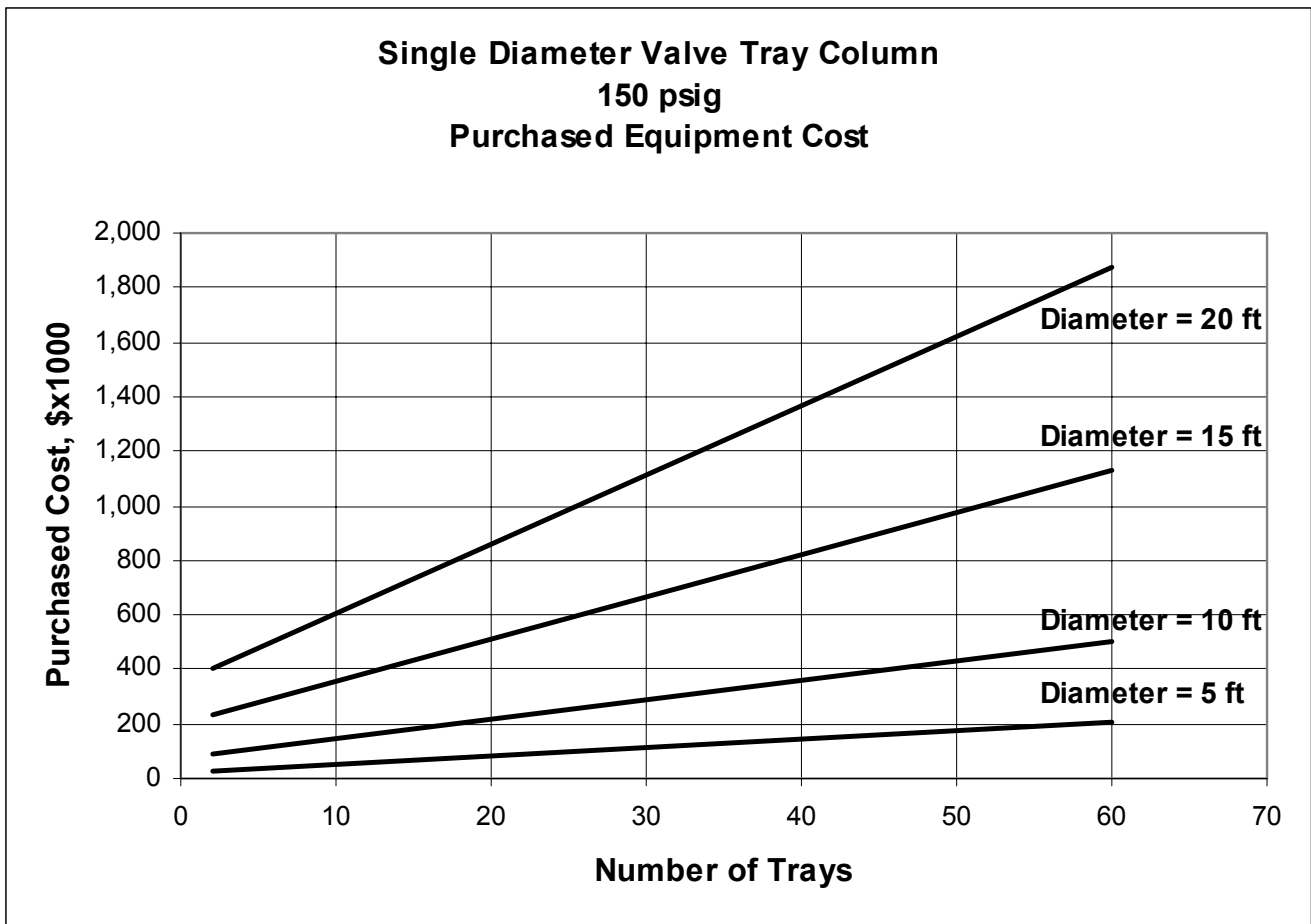
Tray Type: Valve

Tray Spacing: 24 Inches

Tray Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)

Tray Thickness: 0.19 Inches



Sieve Tray Column – 15 psig

Description: Pressure/vacuum column includes vessel shell, heads, single base material (lined or clad, nozzles, manholes (one manhole below and above tray stack or packed section and one manhole every tenth tray or 25 feet of packed height), jacket and nozzles for heating or cooling medium, base ring, lugs, skirt or legs; tray clips, tray supports (if designated), distributor piping, plates.

Design Basis:

1st Quarter 1998 Dollars

Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

Design Temperature: 650 °F

Design Pressure: 15 psig

Height: 17 - 133 feet

Application: Distillation

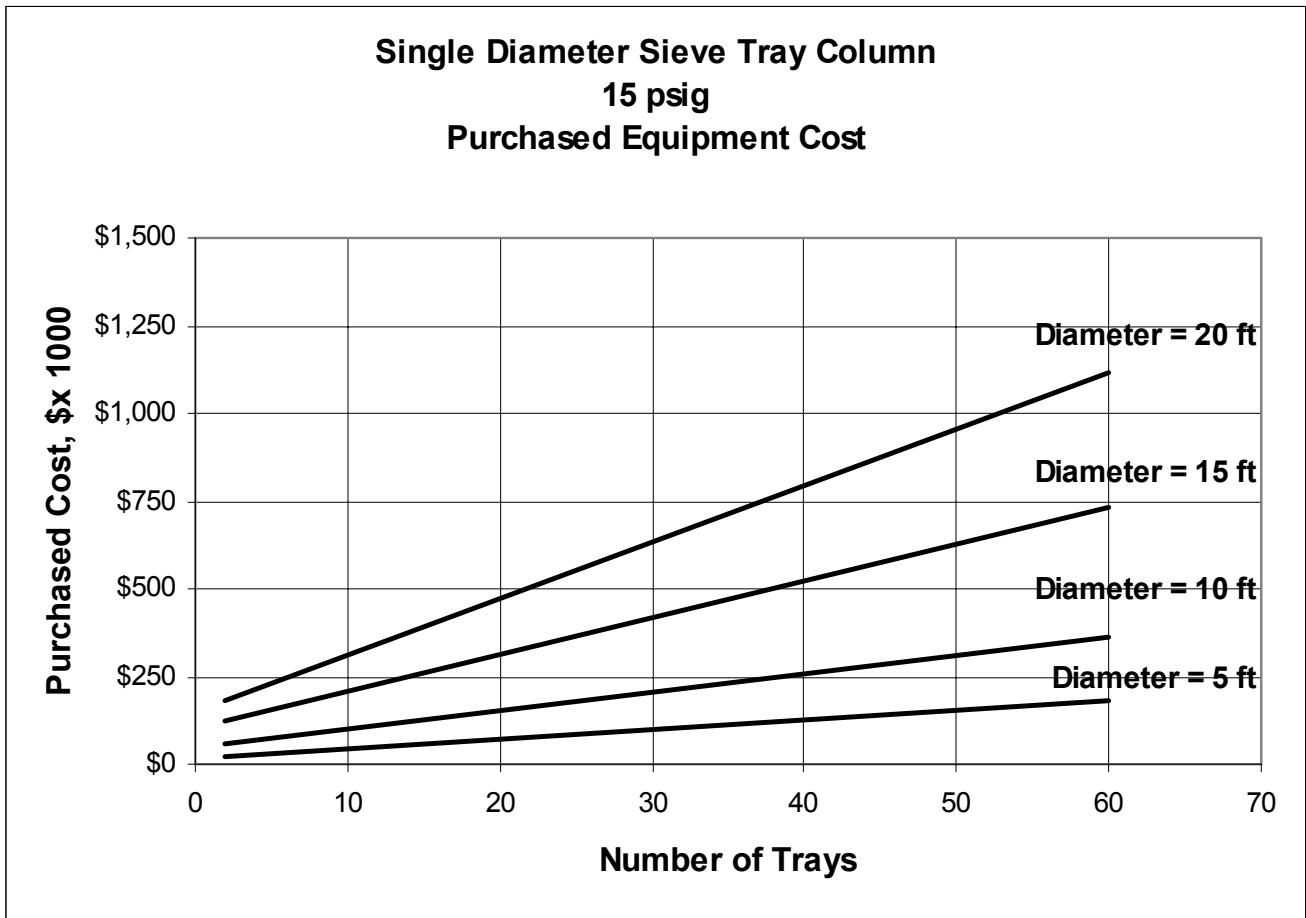
Tray Type: Sieve

Tray Spacing: 24 Inches

Tray Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)

Tray Thickness: 0.19 Inches



Sieve Tray Column – 150 psig

Description: Pressure/vacuum column includes vessel shell, heads, single base material (lined or clad, nozzles, manholes (one manhole below and above tray stack or packed section and one manhole every tenth tray or 25 feet of packed height), jacket and nozzles for heating or cooling medium, base ring, lugs, skirt or legs; tray clips, tray supports (if designated), distributor piping, plates.

Design Basis:

1st Quarter 1998 Dollars

Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

Design Temperature: 650 °F

Design Pressure: 150 psig

Height: 17 - 133 feet

Application: Distillation

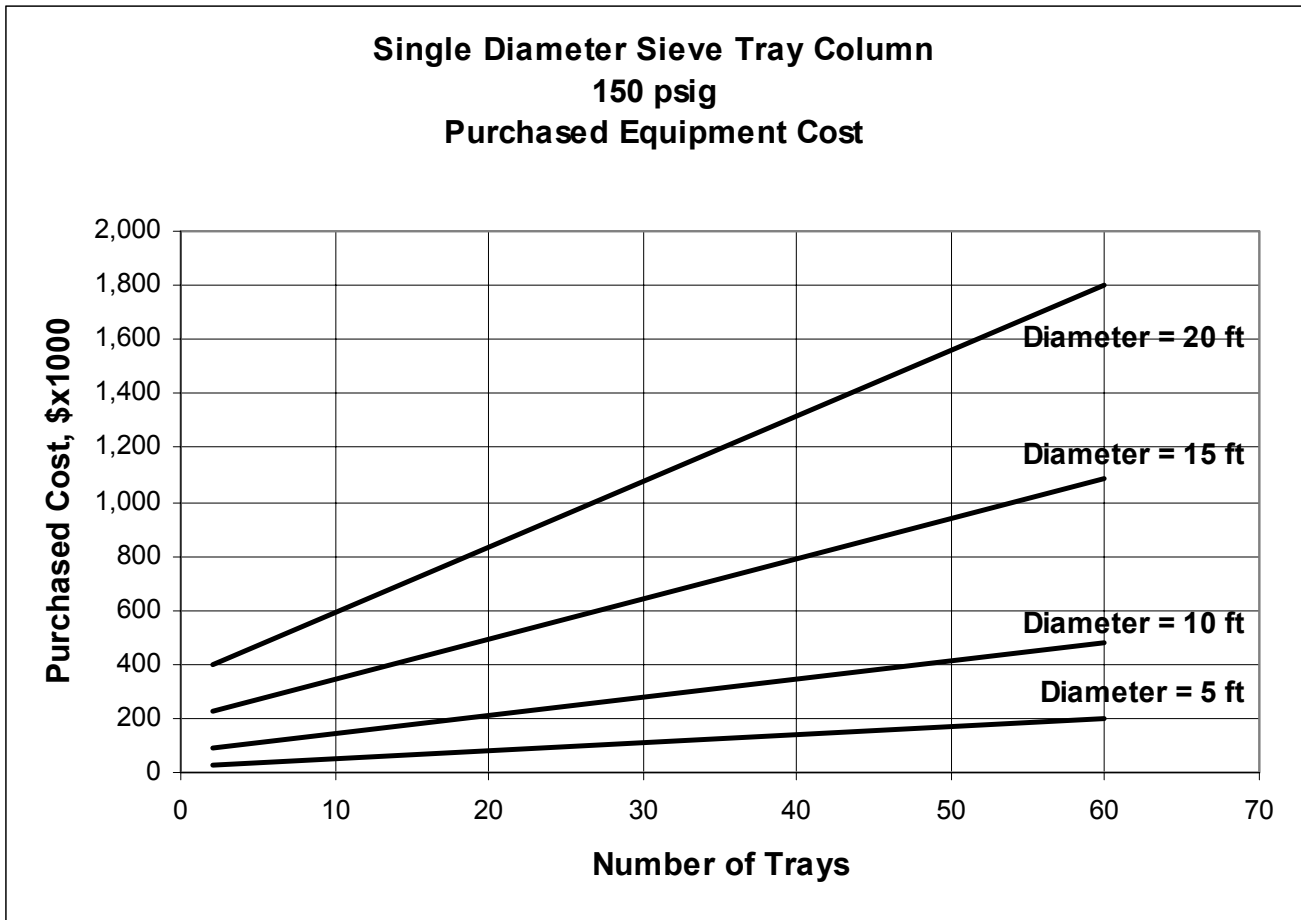
Tray Type: Sieve

Tray Spacing: 24 Inches

Tray Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)

Tray Thickness: 0.19 Inches



Packed Column – 15 psig

Description: Pressure/vacuum column includes vessel shell, heads, single base material (lined or clad, nozzles, manholes (one manhole below and above tray stack or packed section and one manhole every tenth tray or 25 feet of packed height), jacket and nozzles for heating or cooling medium, base ring, lugs, skirt or legs; tray clips, tray supports (if designated), distributor piping, plates, packing not included (see Table 1).

Design Basis:

1st Quarter 1998 Dollars

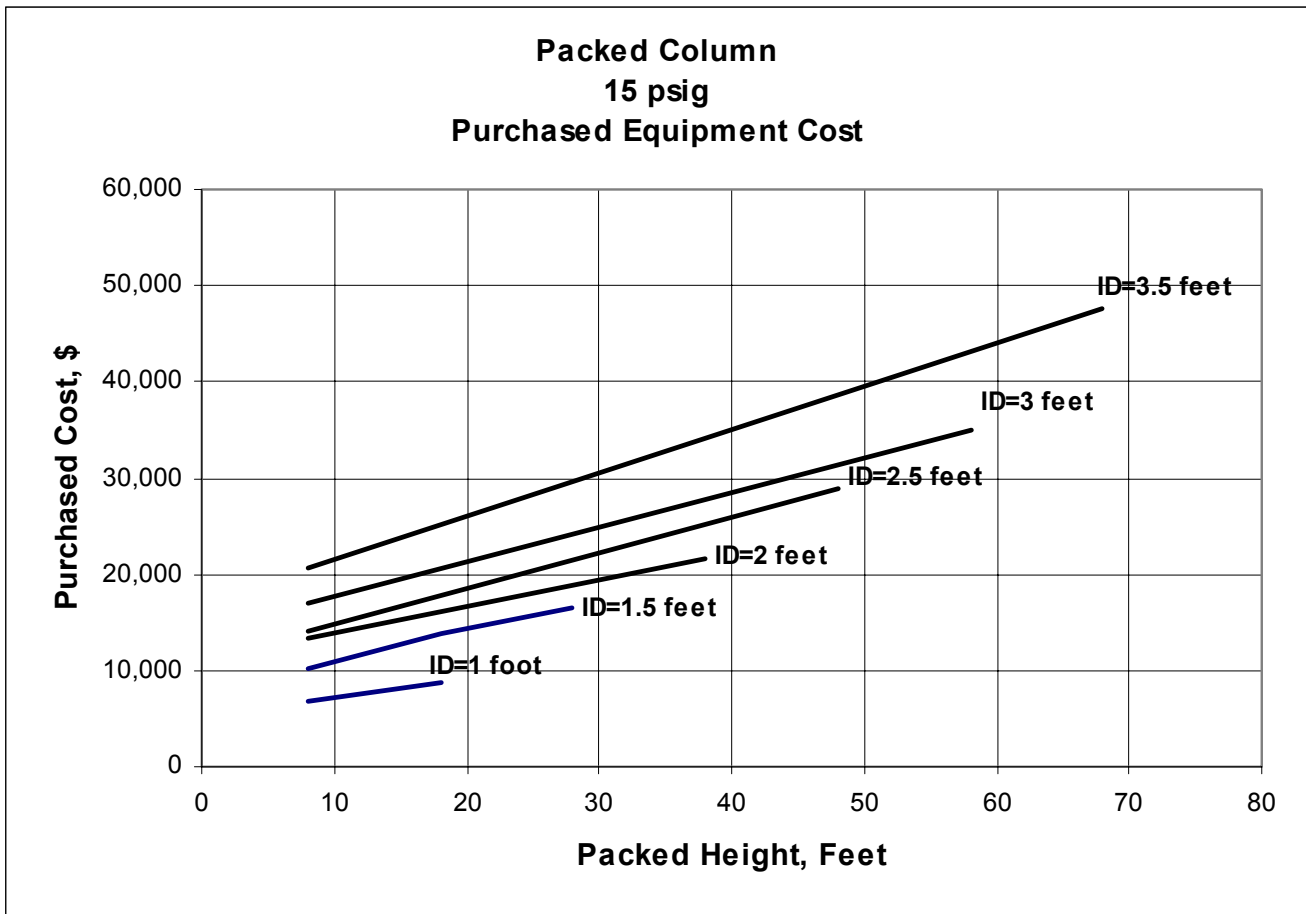
Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

Design Temperature: 650 °F

Design Pressure: 15 psig

Application: Absorption



Packed Column – 150 psig

Description: Pressure/vacuum column includes vessel shell, heads, single base material (lined or clad, nozzles, manholes (one manhole below and above tray stack or packed section and one manhole every tenth tray or 25 feet of packed height), jacket and nozzles for heating or cooling medium, base ring, lugs, skirt or legs; tray clips, tray supports (if designated), distributor piping, plates, packing not included (see Table 1).

Design Basis:

1st Quarter 1998 Dollars

Shell Material: A515

(Carbon Steel Plates for pressure vessels for intermediate and higher temperature service)

Design Temperature: 650 °F

Design Pressure: 150 psig

Application: Absorption

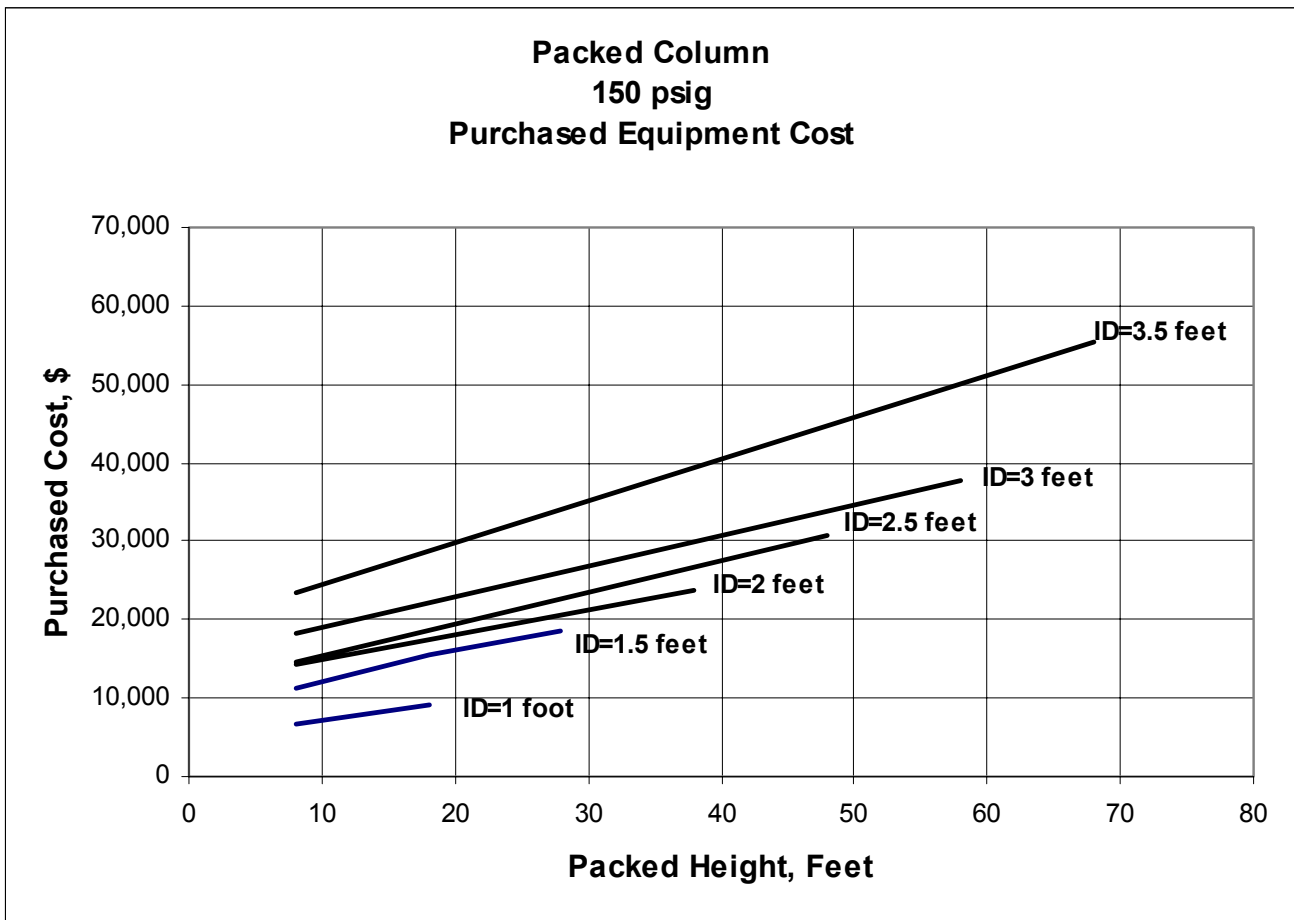


Table 1

Packing Costs

Uninstalled cost, dollar per cubic feet

1st Quarter 1998 Dollars

| Diameter (Inches) | 0.5 | 1.0 | 1.5 | 2.0 | 3.0 |
|--|------------|------------|------------|------------|------------|
| Pall Rings | | | | | |
| Polypropylene | 33 | 29 | 21 | 8 | - |
| Stainless Steel | 130 | 118 | 92 | 76 | - |
| INTALOX Saddles | | | | | |
| Ceramic | 31 | 28 | 23 | 21 | - |
| Porcelain | 32 | 29 | 24 | 21 | - |
| Raschig Rings | | | | | |
| Ceramic | 119 | 14 | 12 | 12 | 11 |
| Porcelain | - | 17 | 15 | 12 | 11 |
| Stainless Steel | - | 111 | 94 | 59 | 54 |
| Carbon Steel | - | 37 | 31 | 20 | 18 |
| <hr style="border: 1px solid black;"/> | | | | | |
| Activated Carbon | 25 | | | | |
| 13X Molecular Sieve | 61 | | | | |
| Silica Gel | 94 | | | | |
| Calcium Chloride | 11 | | | | |

Shell and Tube Heat Exchanger

Description: Shell and tube heat exchanger consists of a bundle of tubes held in a cylindrical shape by plates at either end called tube sheets. The tube bundle placed inside a cylindrical shell. The size of the exchanger is defined as the total outside surface area of the tube bundle. Maximum shell size is 48 Inches.

Design Basis:

1st Quarter 1998 Dollars

Type: Floating Head (BES)/ Fixed Head (BEM)

Shell Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)

Shell Temperature: 650 °F

Shell Pressure: 150 psig

Tube Material: A214

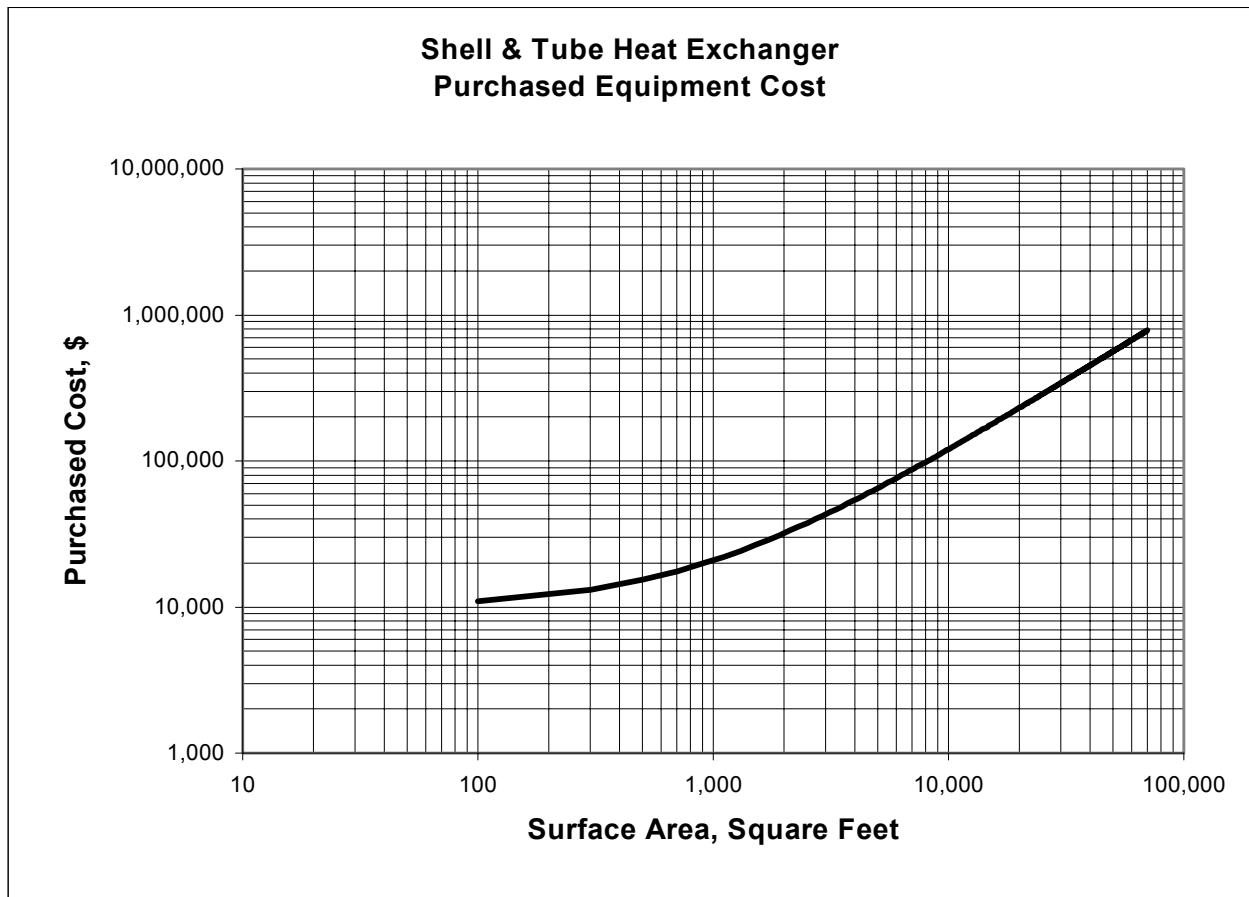
(Electric-resistance-welded carbon steel heat exchanger and condenser tubes)

Tube Temperature: 650 °F

Tube Pressure: 150 psig

Tube Length: 10– 20 Feet

Tube Diameter: 1 Inch



Air Cooler

Description: Variety of plenum chambers, louver arrangements, fin types (or bare tubes), sizes, materials, free-standing or rack mounted, multiple bays and multiple services within a single bay.

Design Basis:

1st Quarter 1998 Dollars

Tube Material: A214

(Electric-resistance-welded carbon steel heat exchanger and condenser tubes)

Tube Length: 6 – 60 Feet

Number of Bays: 1 – 3

Power/ Fan: 2 – 25 Horsepower

Bay Width: 4 – 12 Feet

Design Pressure: 150 psig

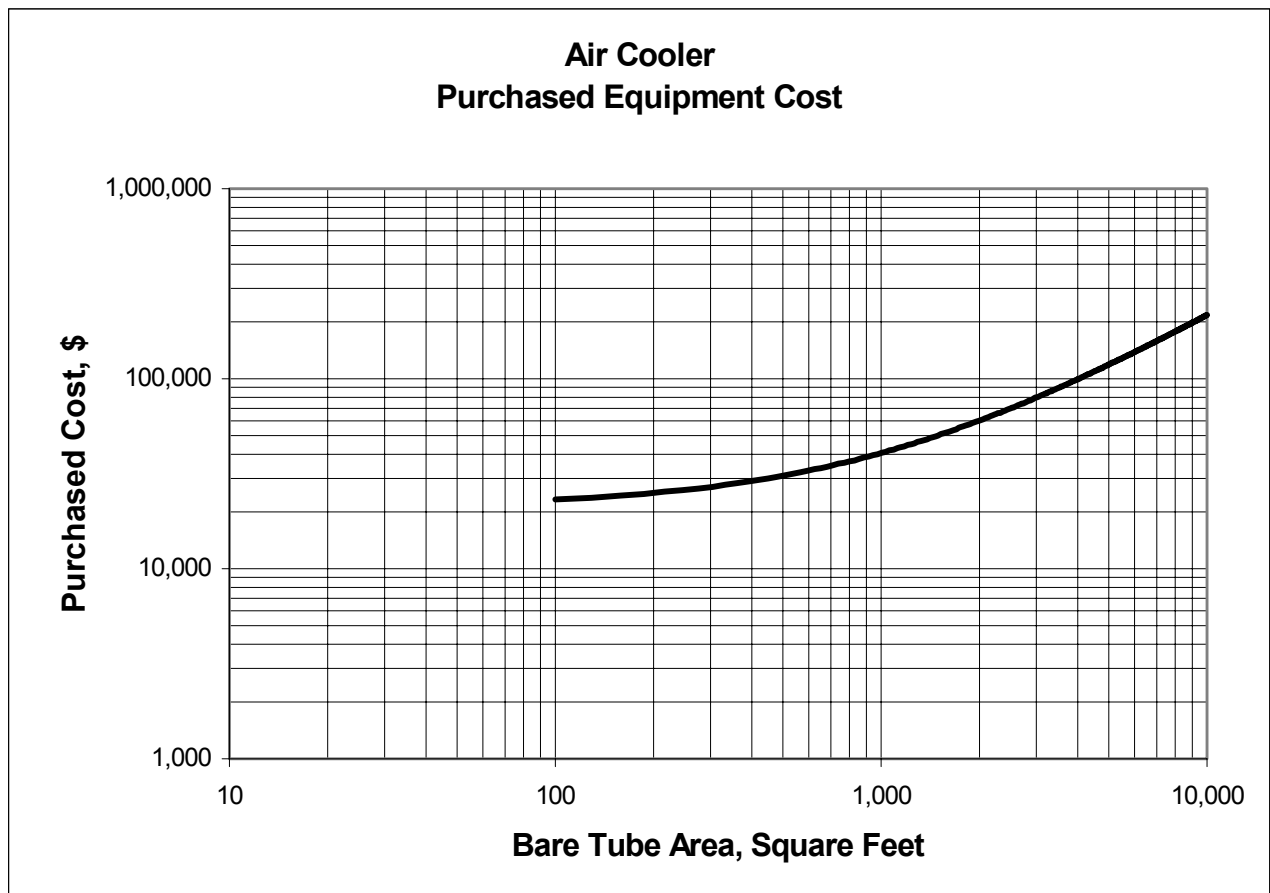
Inlet Temperature: 300 °F

Tube Diameter: 1 Inch

Plenum Type: Transition shaped

Louver Type: Face louvers only

Fin Type: L-footed tension wound Aluminum



Spiral Plate Heat Exchanger

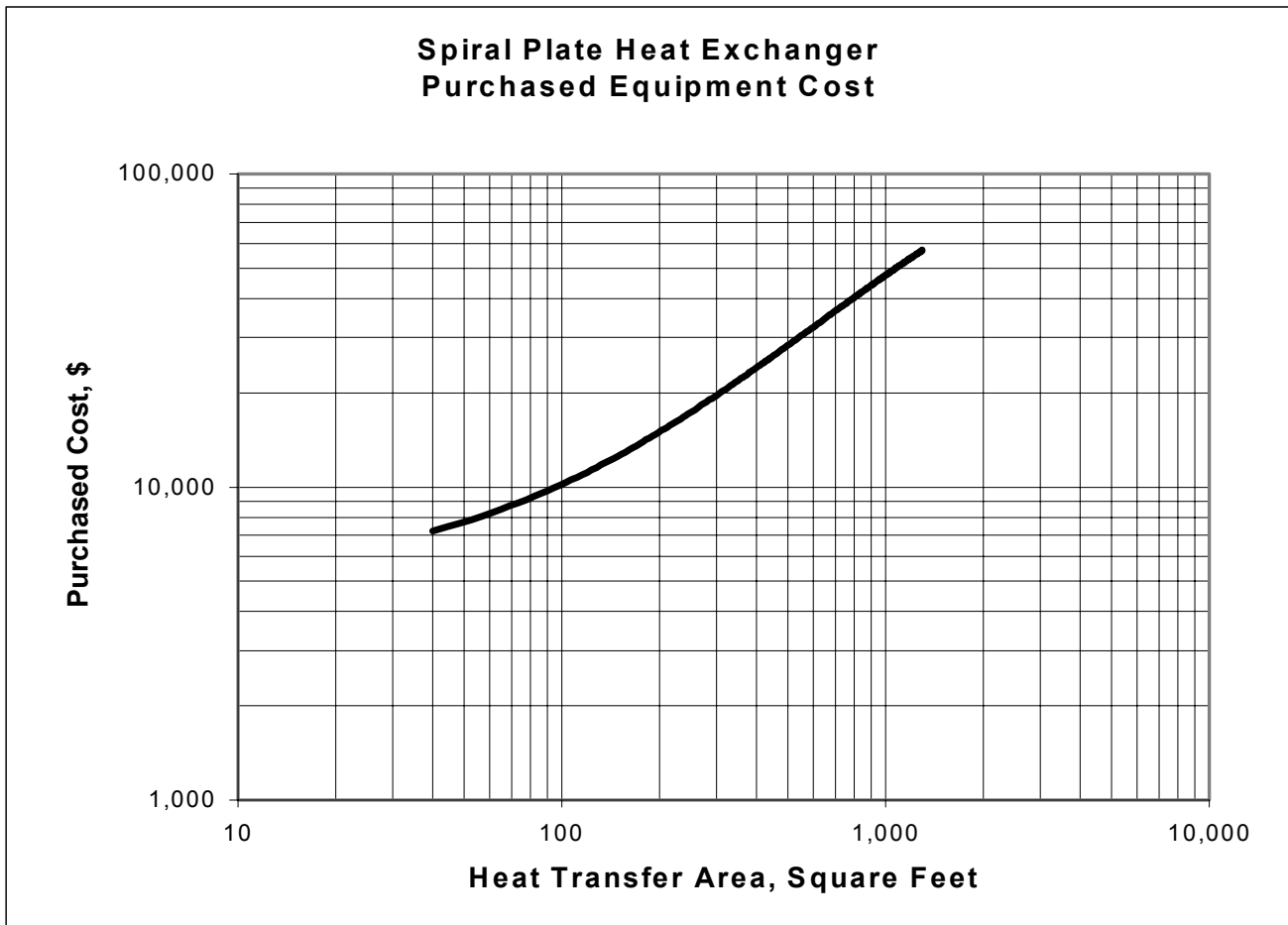
Design Basis:

1st Quarter 1998 Dollars

Material: SS304

(High Alloy Steel - Chromium-Nickel stainless steel plate, sheet and strip for fusion-welded unfired pressure vessels)

Tube Pressure: 150 psig



Furnace

Description: Gas or Oil fired vertical cylindrical type for low heat duty range moderate temperature with long contact time. Walls of the furnace are refractory lined.

Design Basis:

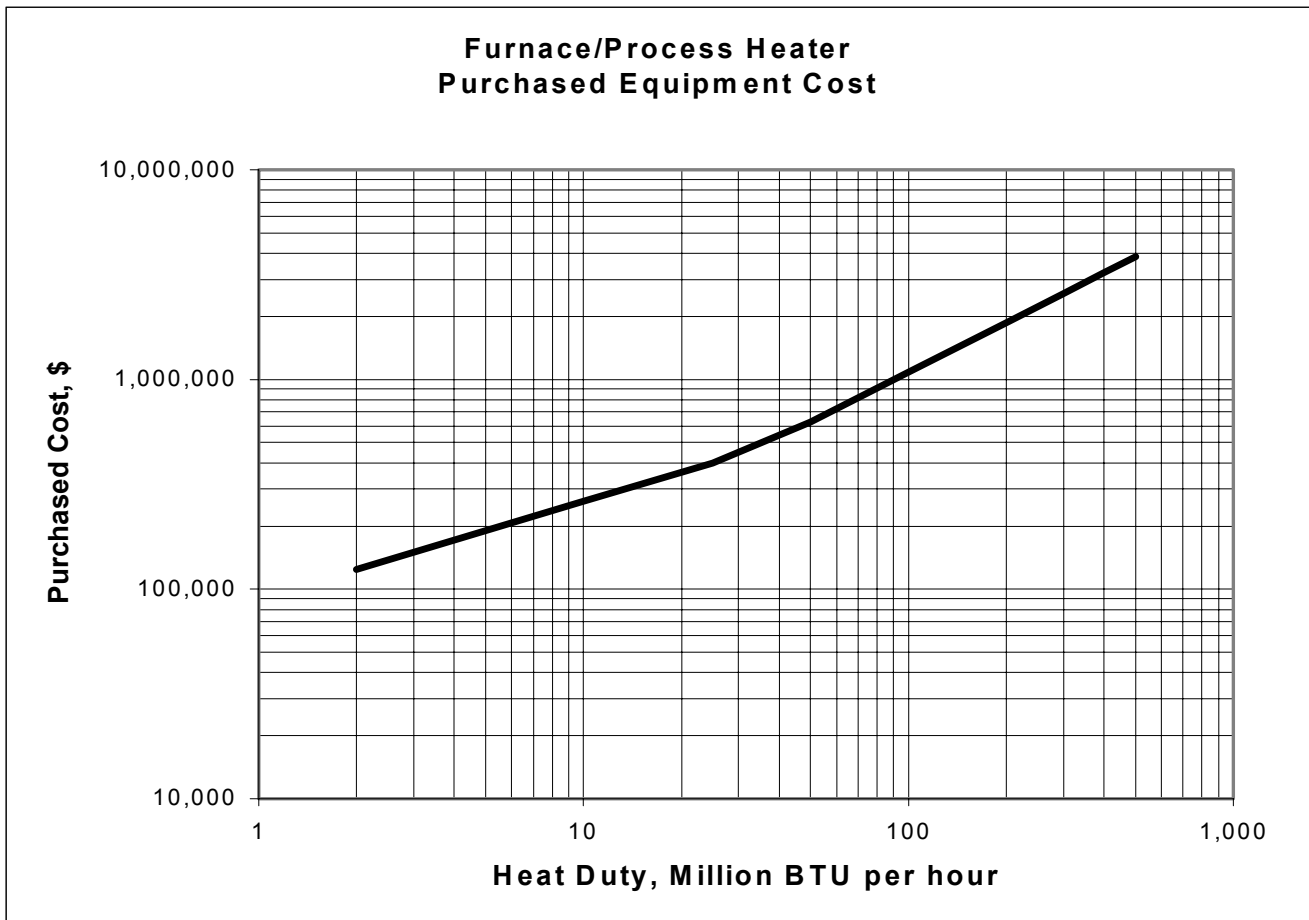
1st Quarter 1998 Dollars

Tube Material: A214

(Electric-resistance-welded carbon steel heat exchanger and condenser tubes)

Design Pressure: 500 psig

Design Temperature: 750 °F



Cooling Tower

Description: Factory Assembled cooling tower includes fans, drivers and basins

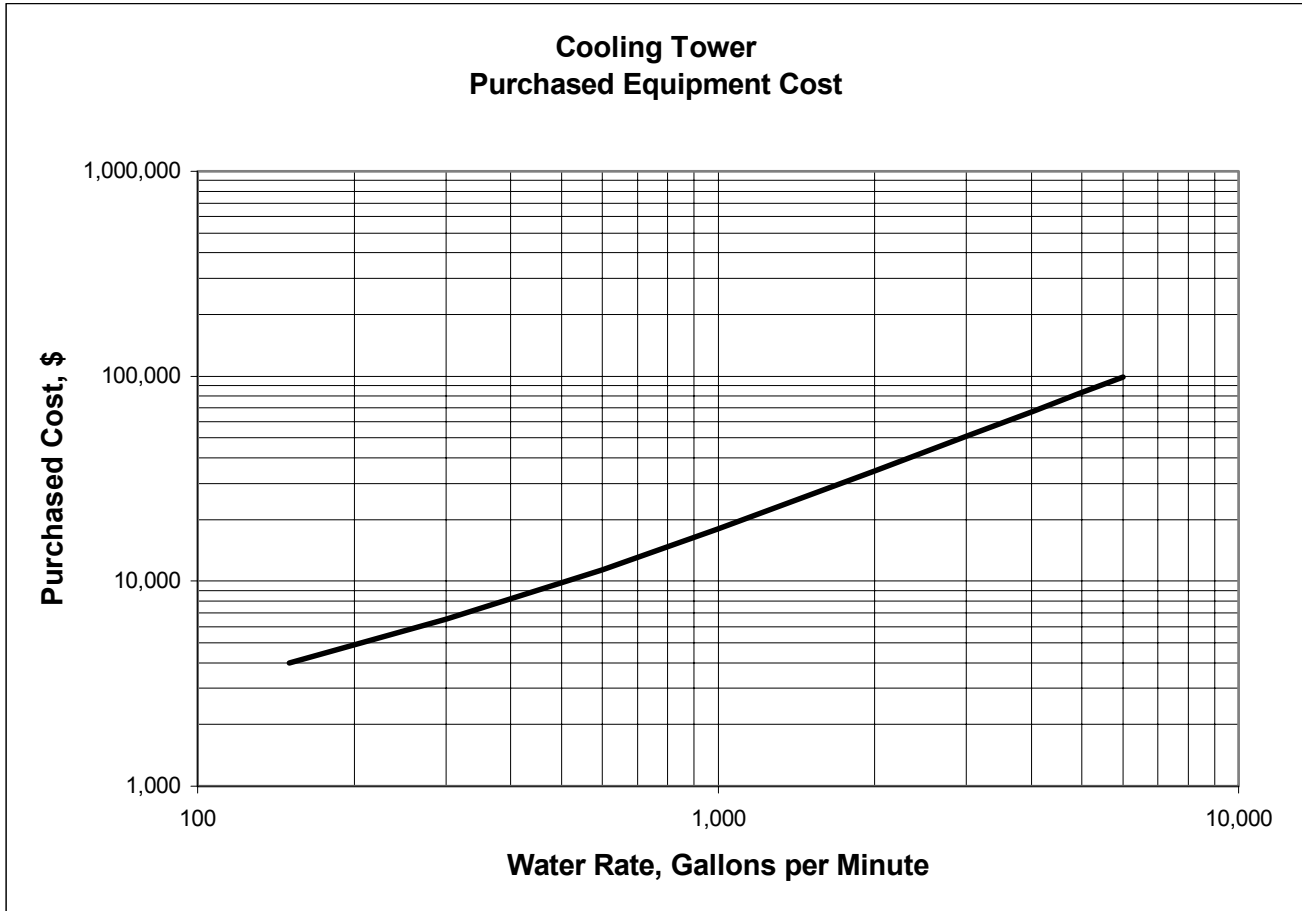
Design Basis:

1st Quarter 1998 Dollars

Temperature Range: 15 °F

Approach Gradient: 10 °F

Wet Bulb Temperature: 75 °F



Package Steam Boiler

Description: Package boiler unit includes forced draft fans, instruments, controls, burners, soot-blowers, feedwater deaerator, chemical injections system, steam drum, mud drum and stack. Shop assembled.

Design Basis:

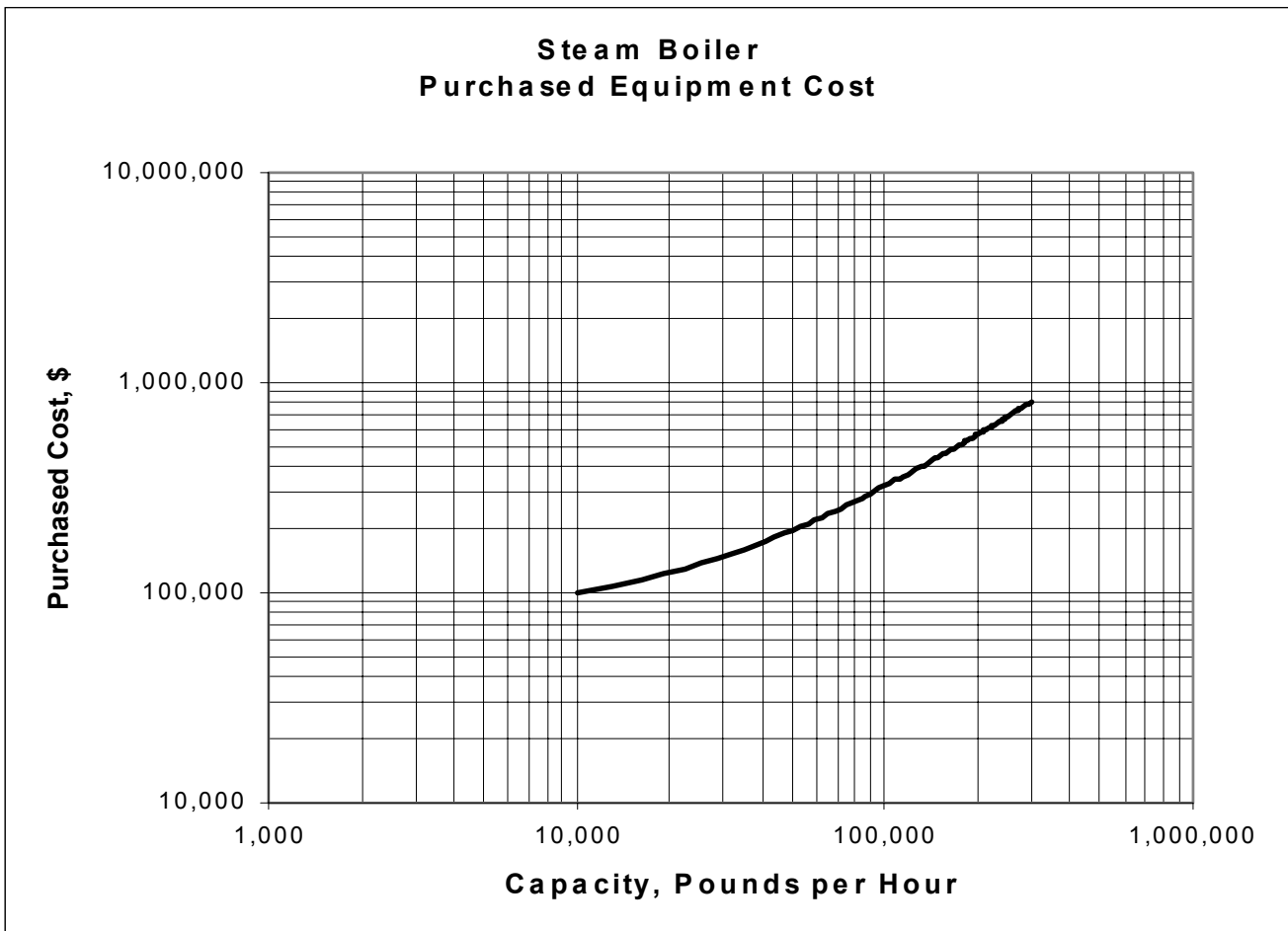
1st Quarter 1998 Dollars

Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)

Pressure: 250 psig

Superheat: 100 °F



Evaporators

Description: Standard vertical tube evaporator and standard horizontal tube evaporator.

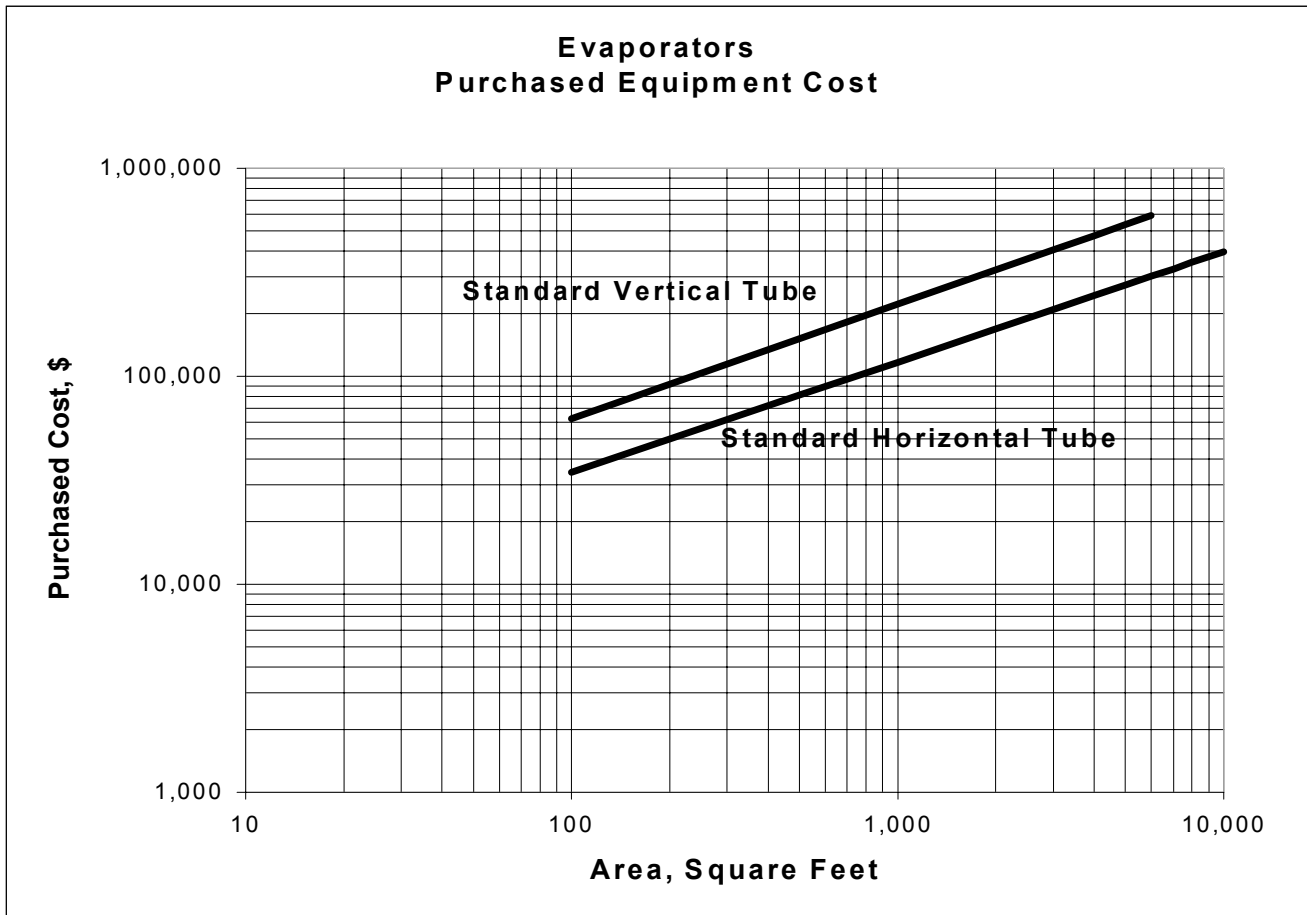
Design Basis:

1st Quarter 1998 Dollars

Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)

Tube Material: Carbon Steel



Crushers

Description: All crushers include motor and drive unit.

Gyratory: Primary crushing of hard and medium hard materials.

Rotary: For coarse, soft materials.

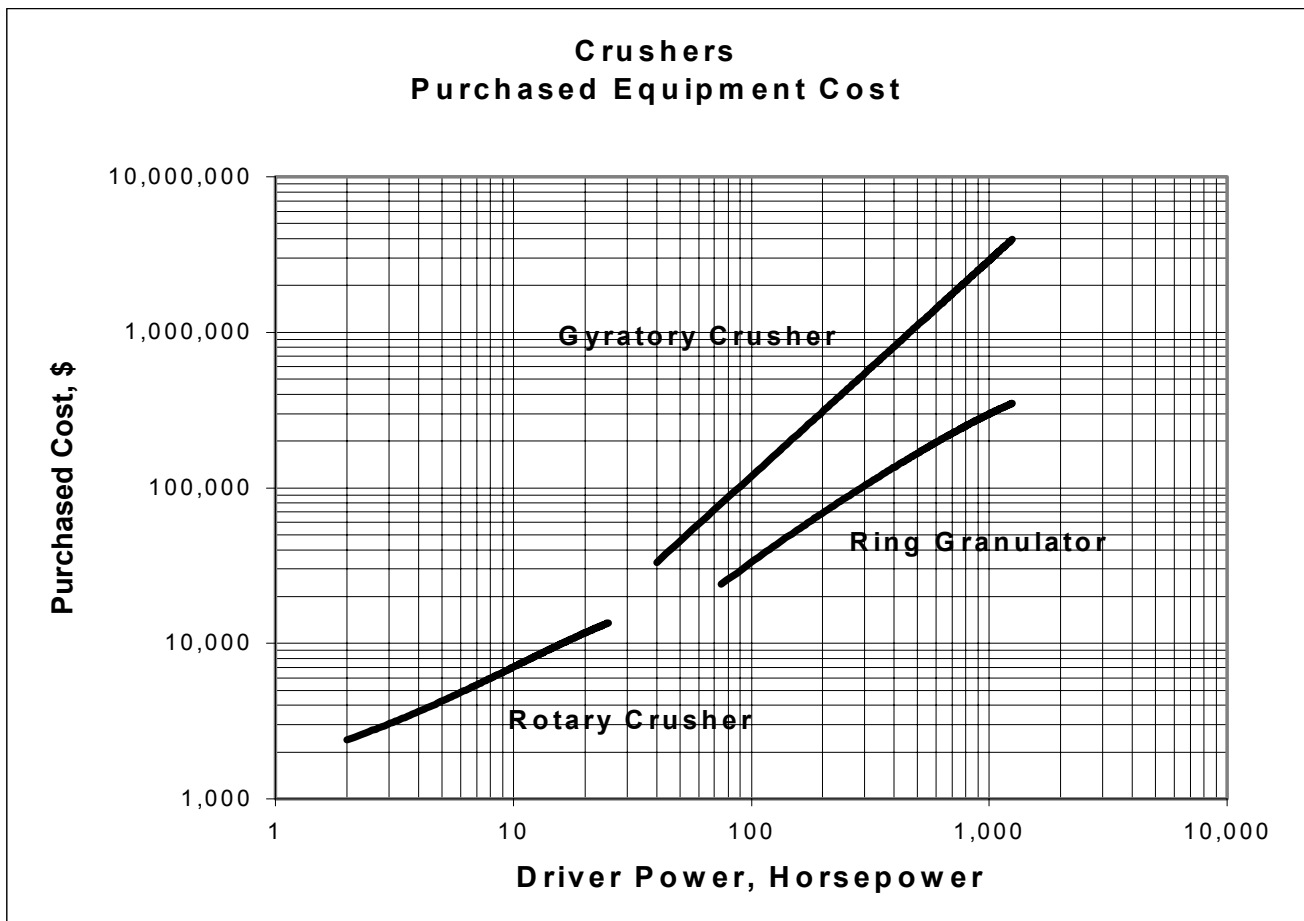
Ring Granulator: For primary and secondary crushing of bituminous and subbituminous coals, lignite, gypsum and some medium hard minerals.

Design Basis:

1st Quarter 1998 Dollars

Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)



Mills

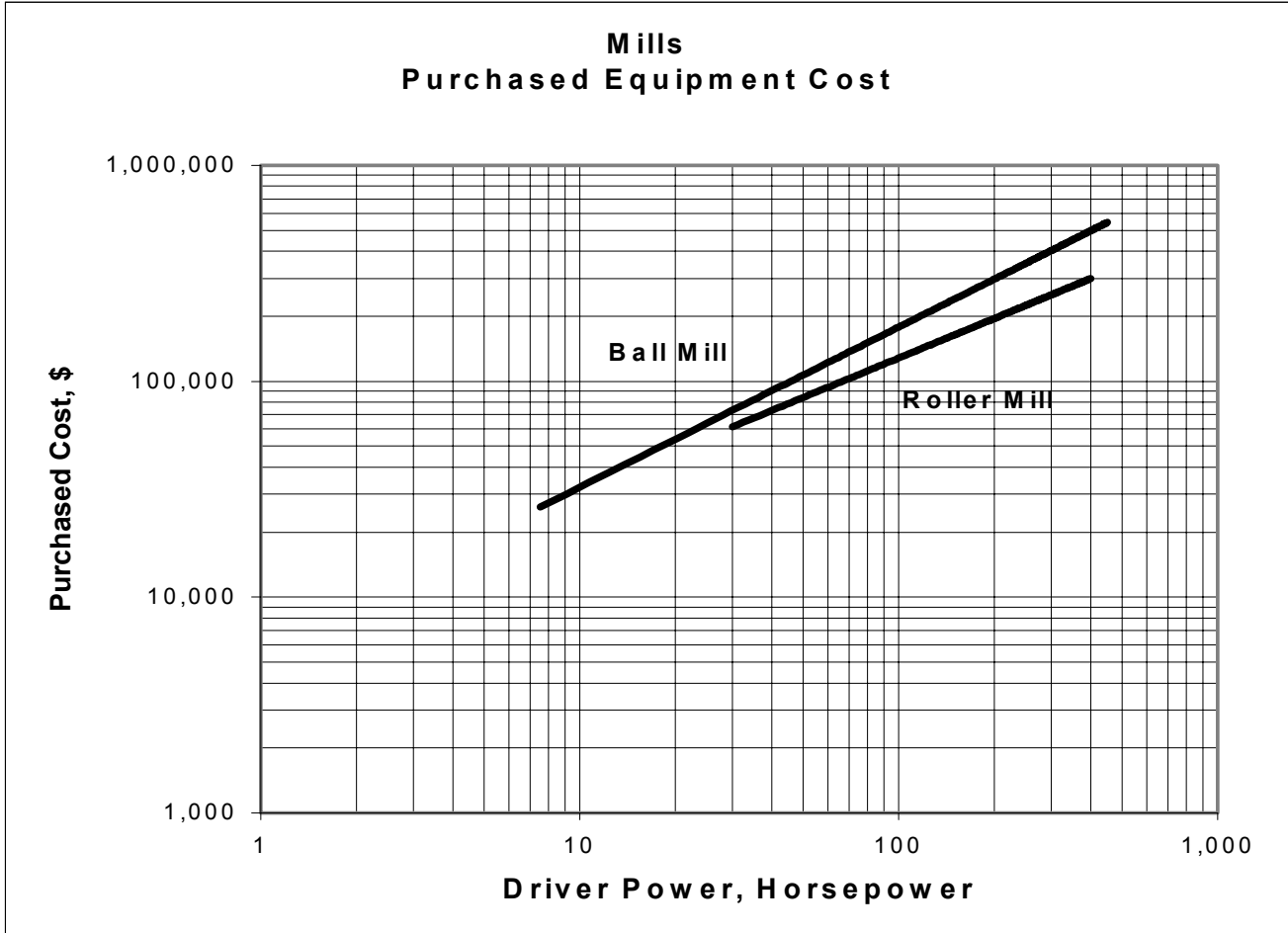
Description: All units include mill, bearings, gears, lube system and vendor-supplied instruments. Ball mill includes initial ball charge.

Design Basis:

1st Quarter 1998 Dollars

Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)



Dryers

Description:

Atmospheric tray batch dryer includes solid materials.

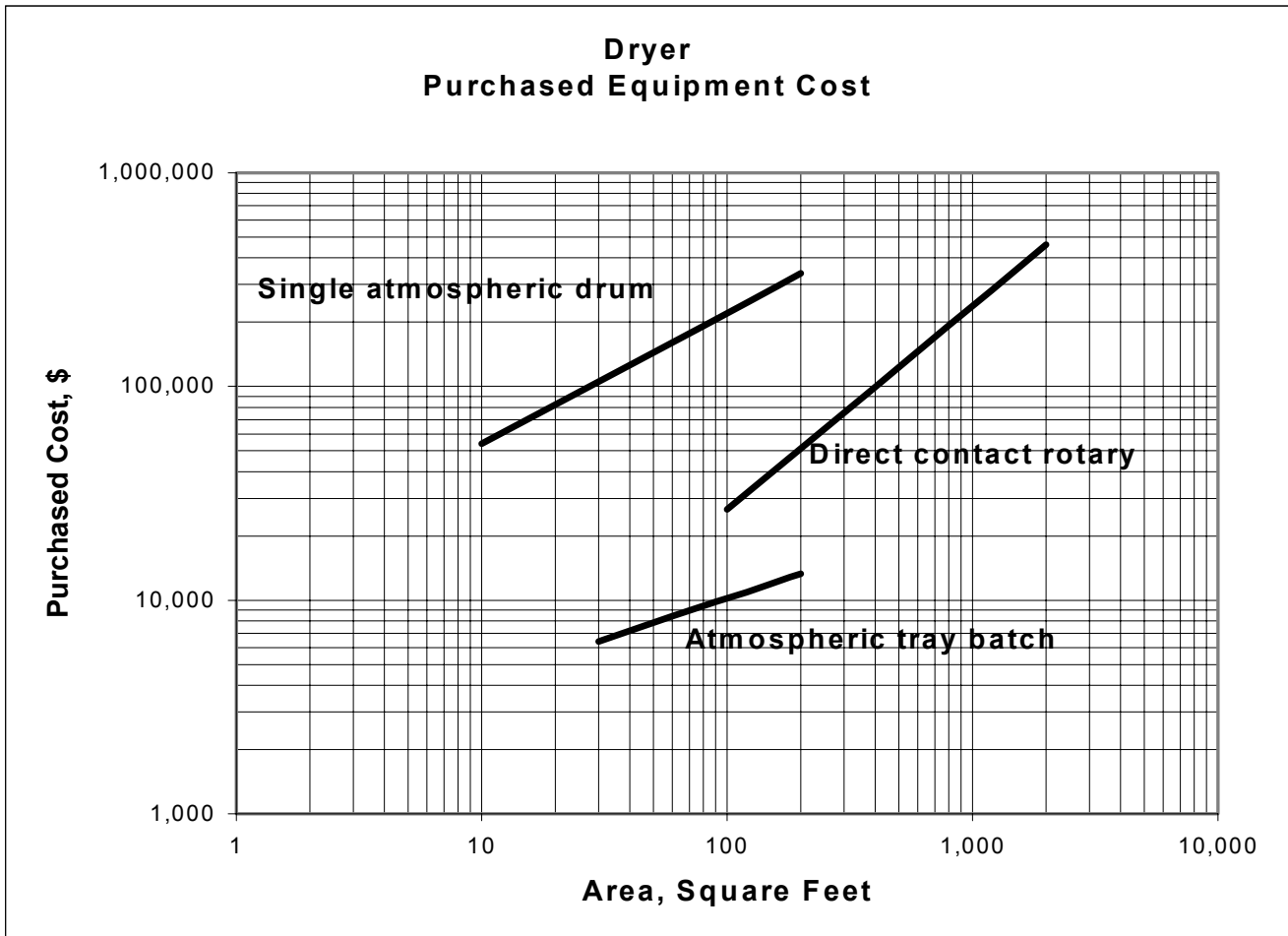
Rotary and Drum dryers include motor and drive unit.

Design Basis:

1st Quarter 1998 Dollars

Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)



Centrifuges

Description: Centrifuges include motor and drive unit.

Reciprocating Conveyor with continuous filtering centrifuge for free-draining granular solids, horizontal bowl, removal by reciprocating piston.

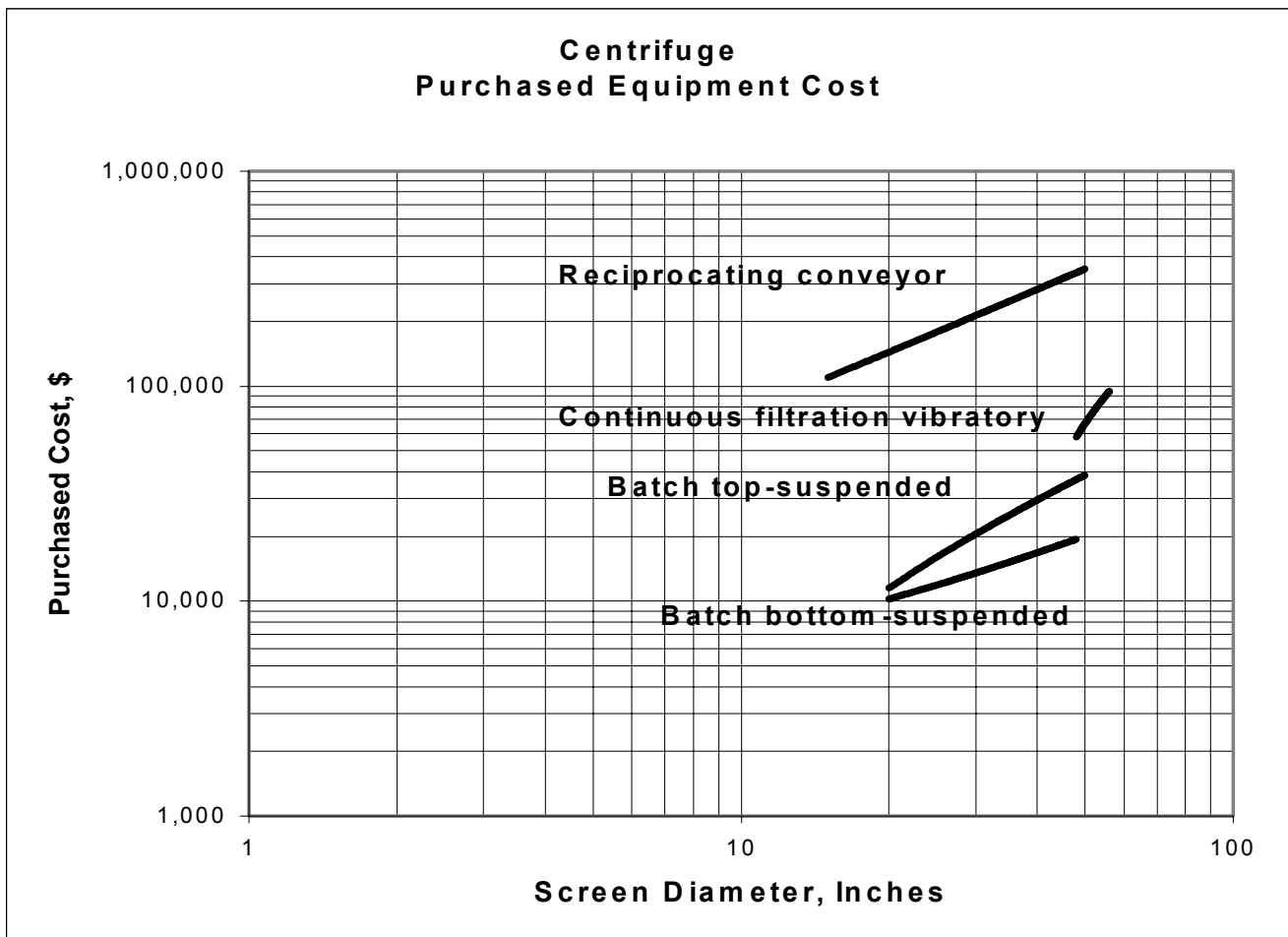
Continuous Filtration Vibratory Centrifuge with solids removal by vibratory screen for dewatering of course solids.

Design Basis:

1st Quarter 1998 Dollars

Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)



Filters

Description:

Cartridge Filter consists of a tank containing one or more disposable cartridges. Contains 5-micron cotton filter.

Drum Filter is a vacuum type, multi compartment cylinder shell with internal filtrate piping with polypropylene filter cloth, feed box with inlet and drain nozzles, suction valve, discharge trough, driver consisting of rotor, drive motor base plate, worm, gear reducer and two pillow block bearing with supports.

Defaults for Drum Filter

medium filtration rate,

0.5 tons per day/ square feet solids handling rate,

20% consistency (percent of solids in feed stream).

Tubular Fabric Filters are a bank of three without automatic cleaning option.

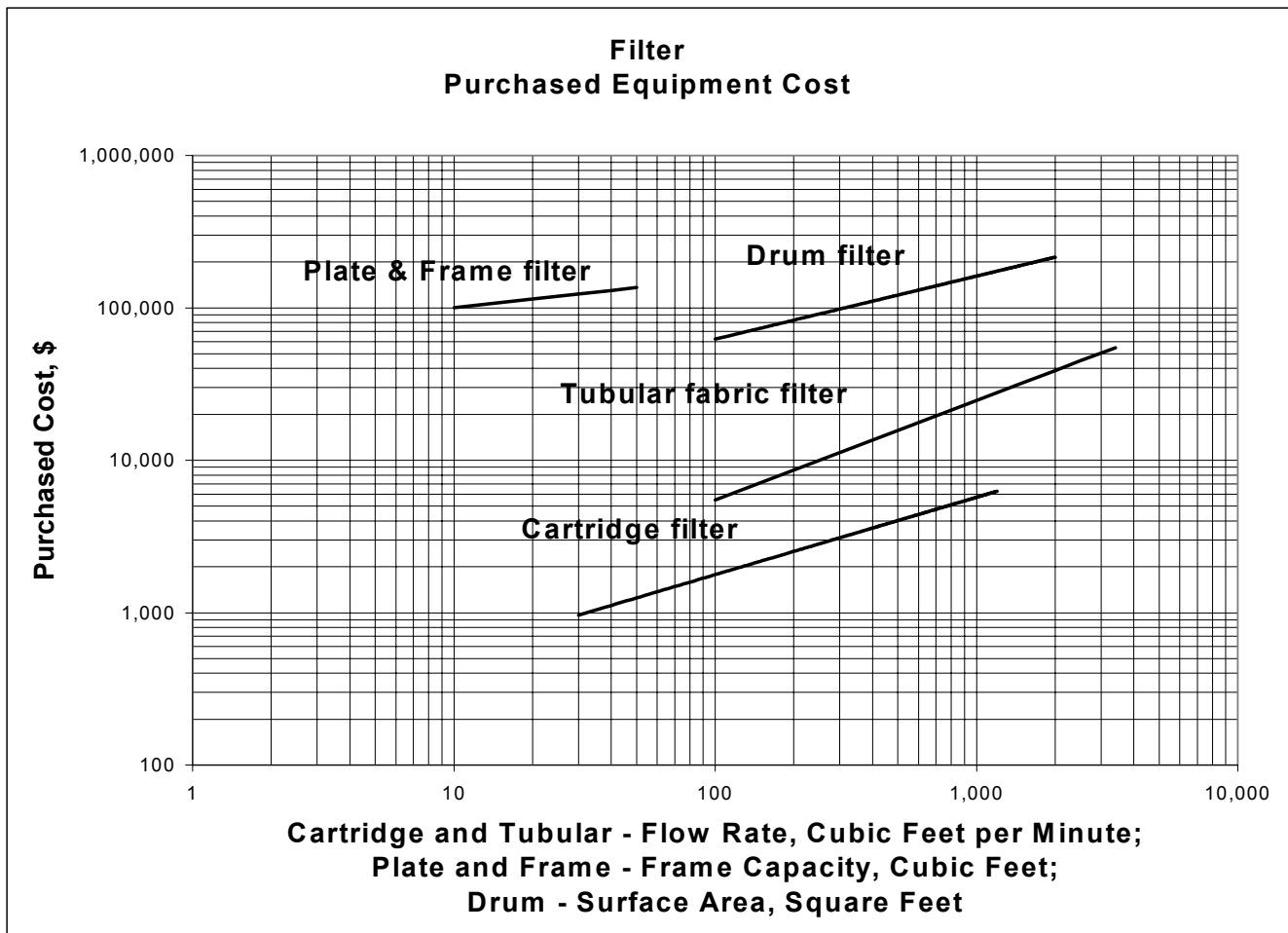
Plate and Frame Filter default material is rubber-lined carbon steel.

Design Basis:

1st Quarter 1998 Dollars

Material: A285C

(Low and intermediate strength carbon steel plates for pressure vessels.)



Agitator

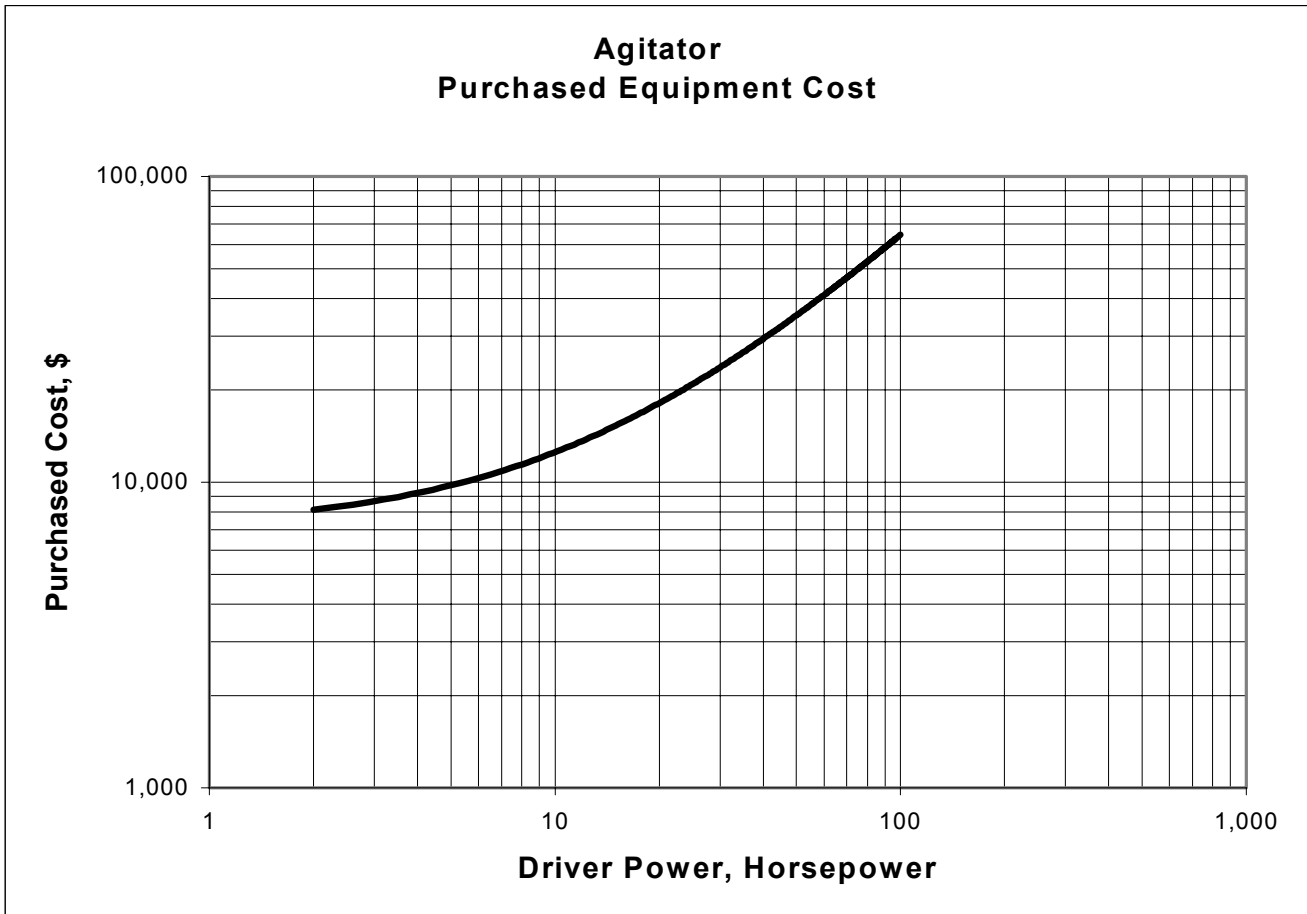
Description: Fixed propeller mixer with motor and gear drive. Includes motor, gear drive, shaft and impeller.

Design Basis:

1st Quarter 1998 Dollars

Material: A285C
(Low and intermediate strength carbon steel plates for pressure vessels.)

Speed: 1800 RPM



Rotary Pump

Description: Rotary (sliding vanes) pump includes motor driver.

Design Basis:

1st Quarter 1998 Dollars

Material: Cast Iron

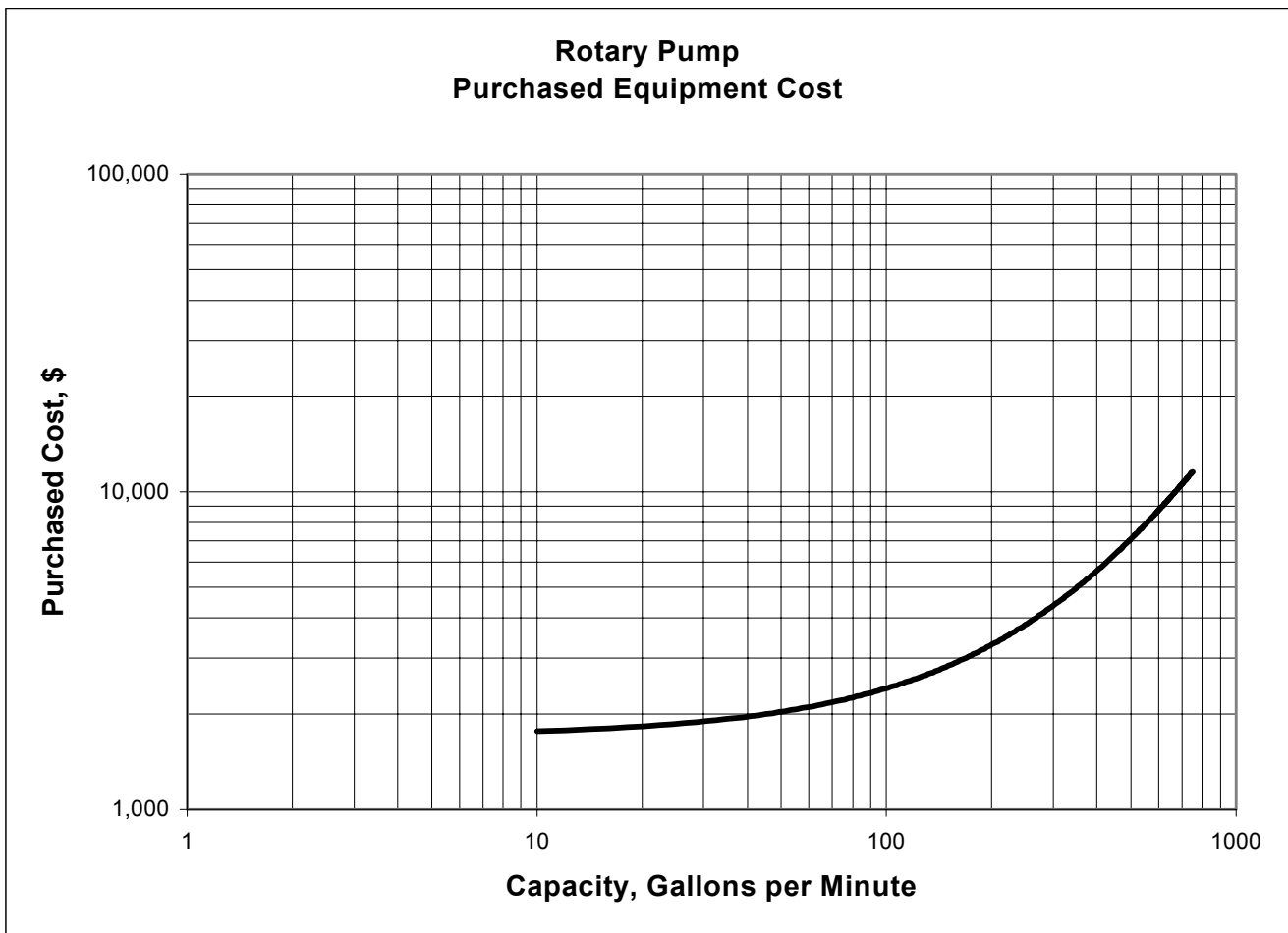
Temperature: 68 °F

Power: 25 – 20 Horsepower

Speed: 1800 RPM

Liquid Specific Gravity: 1

Efficiency: 82%



Inline Pump

Description: General service in-line pump includes pump and motor driver.

Design Basis:

1st Quarter 1998 Dollars

Material: Carbon Steel

Temperature: 120 °F

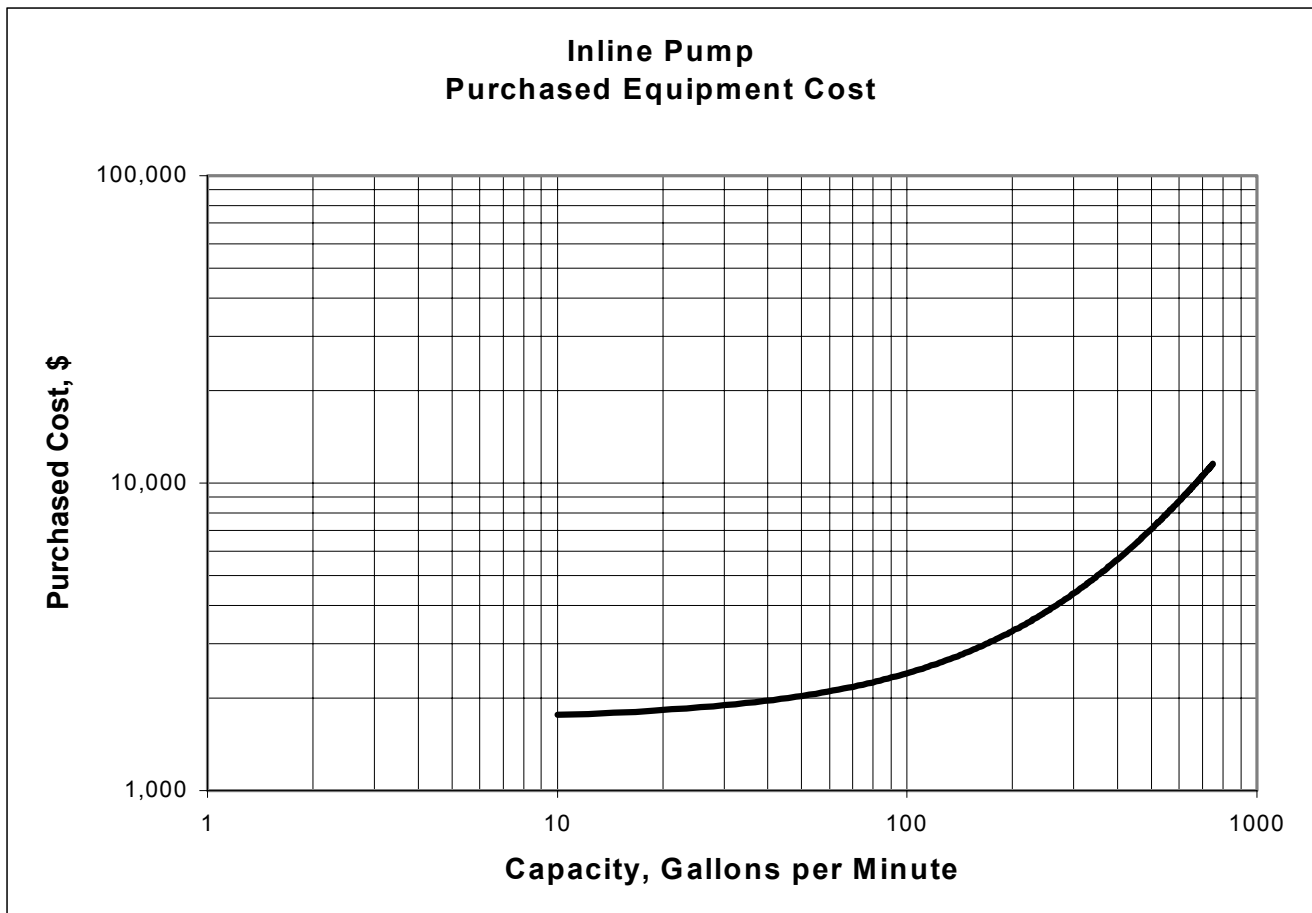
Speed: 1800 RPM

Liquid Specific Gravity: 1

Efficiency: <50 GPM = 60%
50 – 199 GPM = 65%
100 – 500 GPM = 75%
> 500 GPM = 82%

Driver Type: Standard motor

Seal Type: Single mechanical seal



Centrifugal Pump

Description: Single and multistage centrifugal pumps for process or general service when flow/head conditions exceed general service. Split casing not a cartridge or barrel. Includes standard motor driver.

Design Basis:

1st Quarter 1998 Dollars

Material: Carbon Steel

Design Temperature: 120 °F

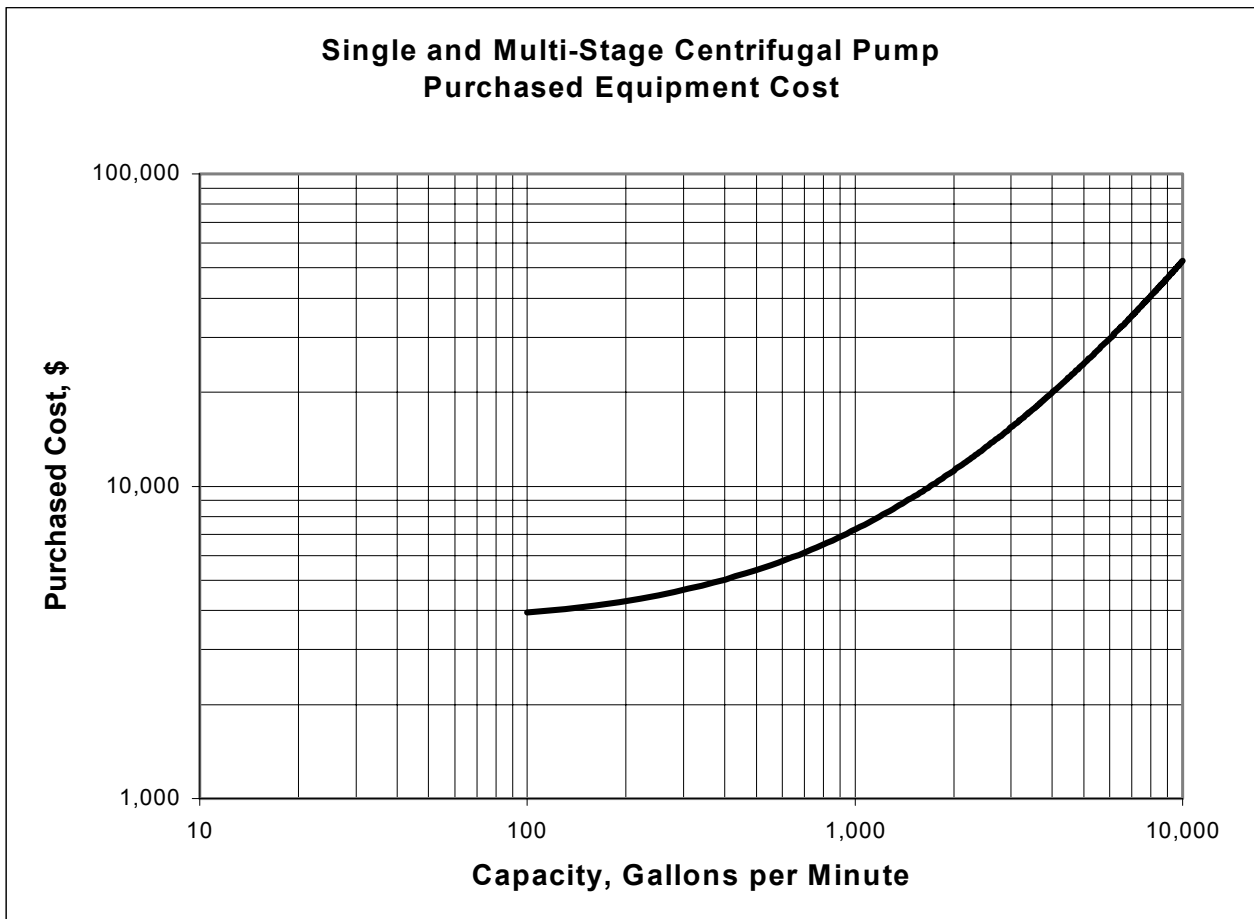
Design Pressure: 150 psig

Liquid Specific Gravity: 1

Efficiency: <50 GPM = 60%
50 – 199 GPM = 65%
100 – 500 GPM = 75%
> 500 GPM = 82%

Driver Type: Standard motor

Seal Type: Single mechanical seal



Reciprocating Pump

Description: Reciprocating duplex with steam driver. Triplex (plunger) with pump-motor driver.

Design Basis:

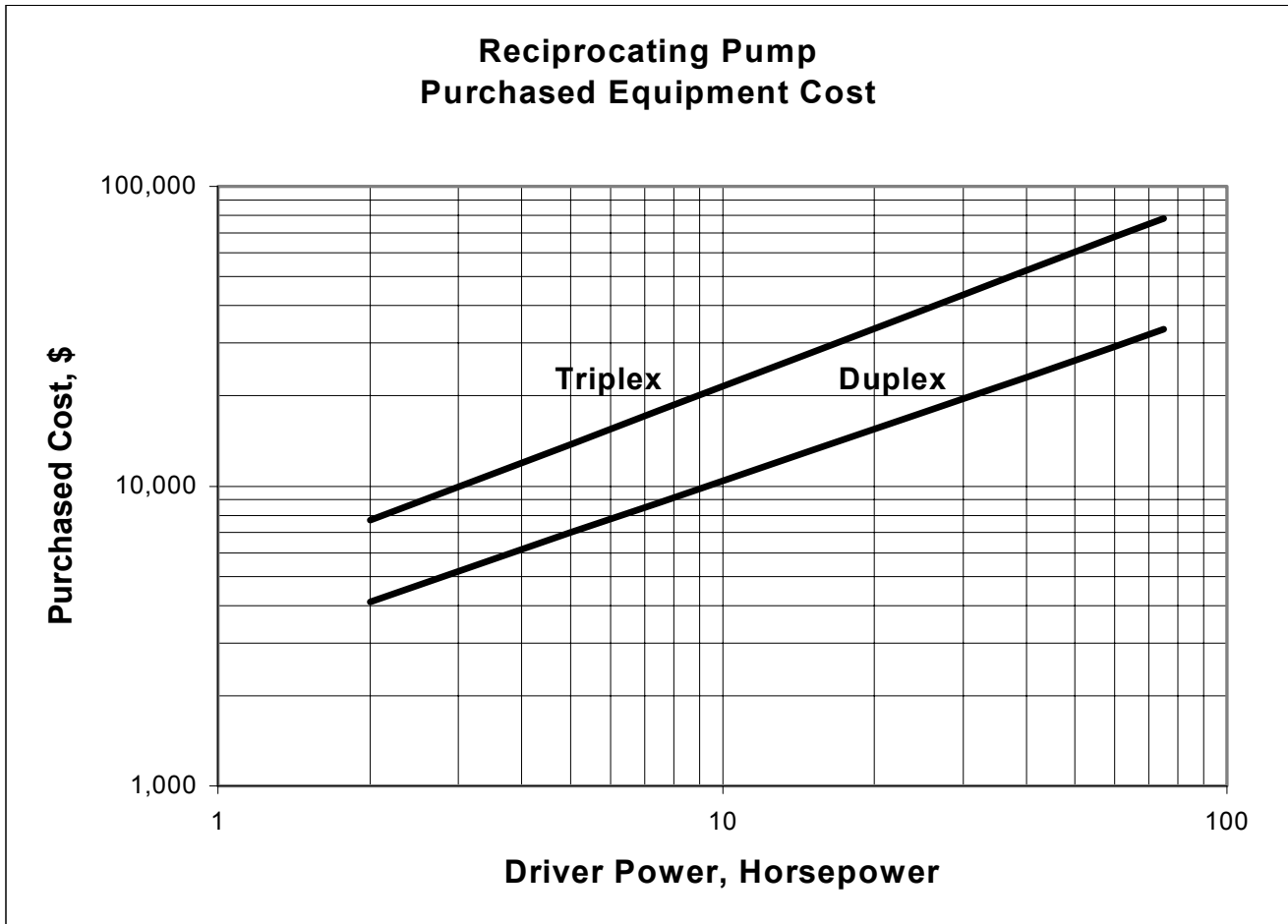
1st Quarter 1998 Dollars

Material: Carbon Steel

Design Temperature: 68 °F

Liquid Specific Gravity: 1

Efficiency: 82%



Vacuum Pump

Description: Mechanical oil-sealed vacuum pump includes pump, motor and drive unit.

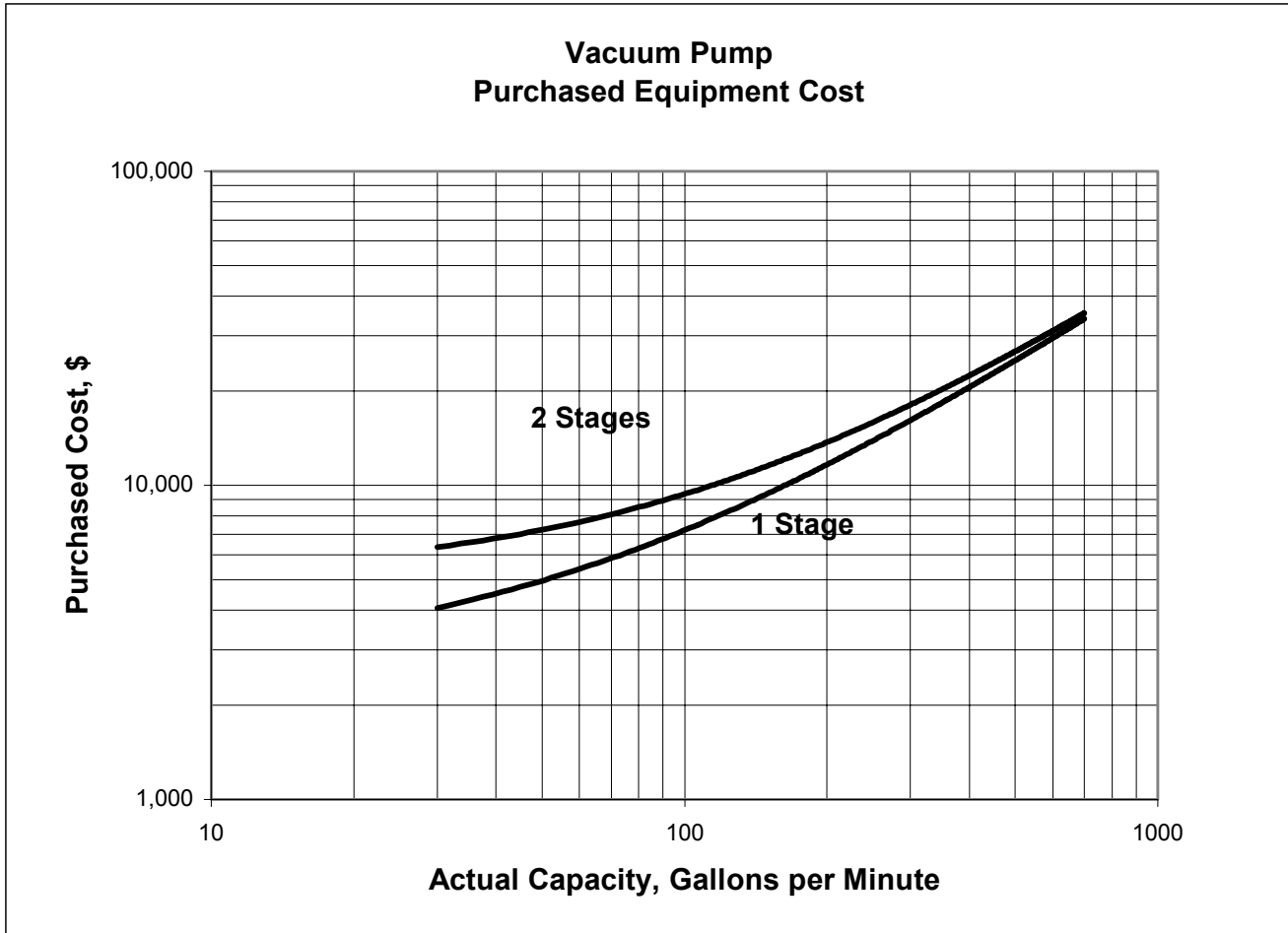
Design Basis:

1st Quarter 1998 Dollars

Material: Carbon Steel

First Stage: 0.01 MM HG (Mercury)

Second Stage: 0.0003 MM HG (Mercury)



Reciprocating Compressor

Description: Reciprocating compressor with gear reducer, couplings, guards, base plate, compressor unit, fittings, interconnecting piping, vendor-supplied instruments, lube/seal system. Does not include intercoolers or aftercoolers and interstage knock-out drums.

Design Basis:

1st Quarter 1998 Dollars

Material: Carbon Steel

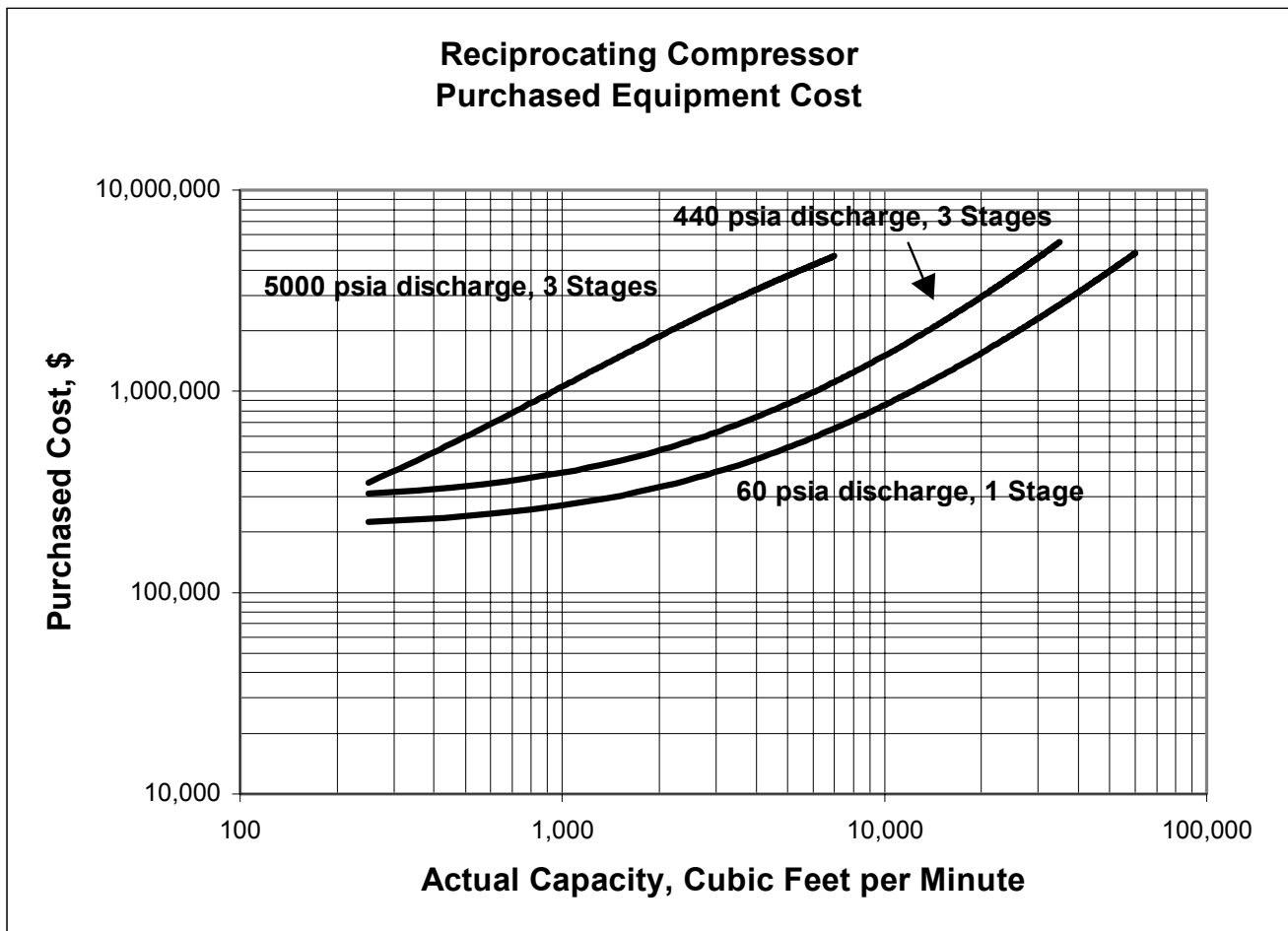
Inlet Temperature: 68 °F

Inlet Pressures: 14.7/ 14.7/ 165 psia

Pressure Ratios: 4:1/ 30:1/ 30:1

Molecular Weight: 30

Specific Heat Ratio: 1.22



Centrifugal Compressor

Description: Axial (inline) centrifugal gas compressor with motor driver. Excludes intercoolers and knock-out drums.

Design Basis:

1st Quarter 1998 Dollars

Material: Carbon Steel

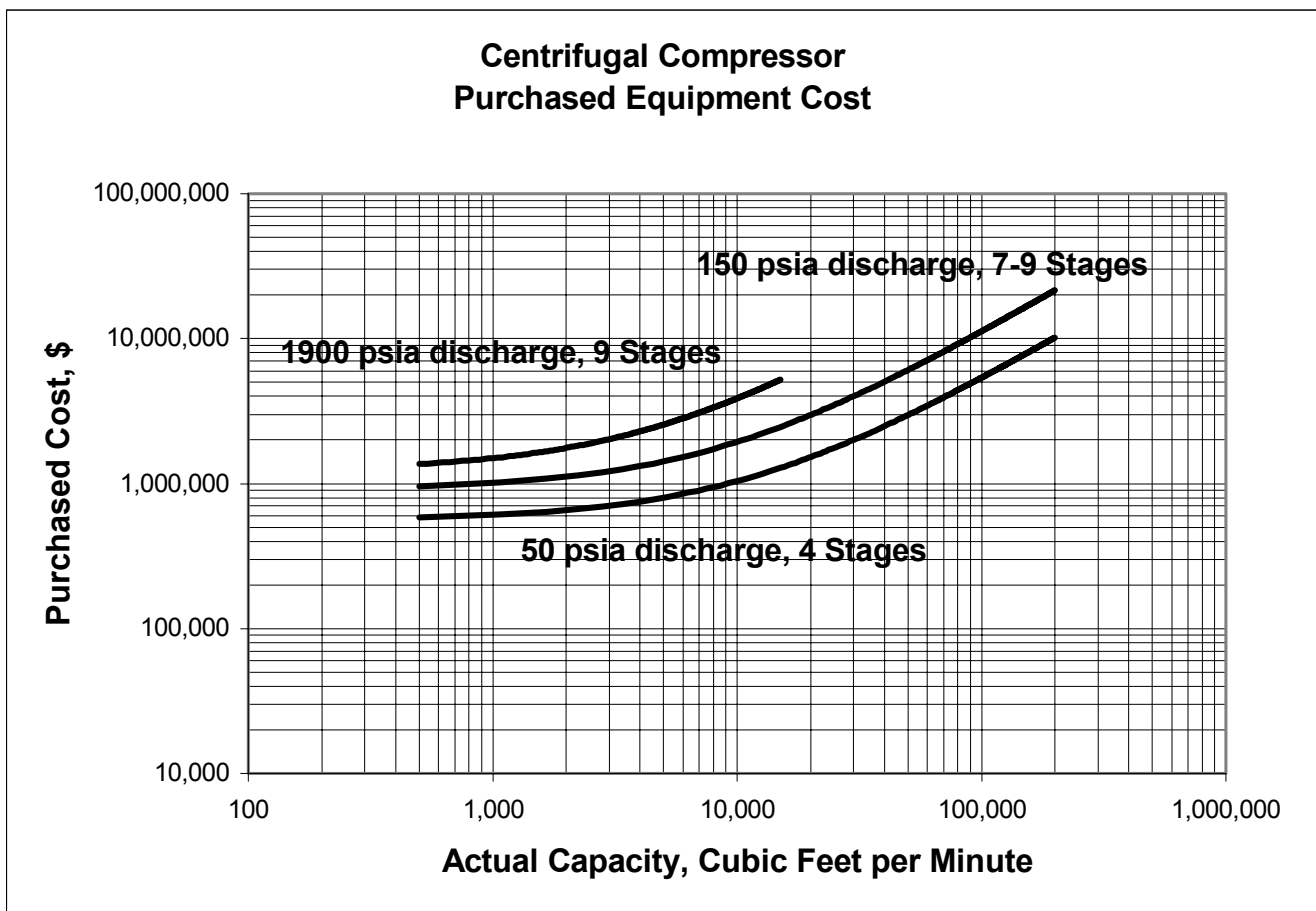
Inlet Temperature: 68 °F

Inlet Pressures: 14.7/ 14.7/ 190 psia

Pressure Ratios: 3:1/ 10:1/ 10:1

Molecular Weight: 29

Specific Heat Ratio: 1.4



Centrifugal Fan

Description: Centrifugal fans move gas through a low pressure drop system. Maximum pressure rise is about 2 PSI.

Design Basis:

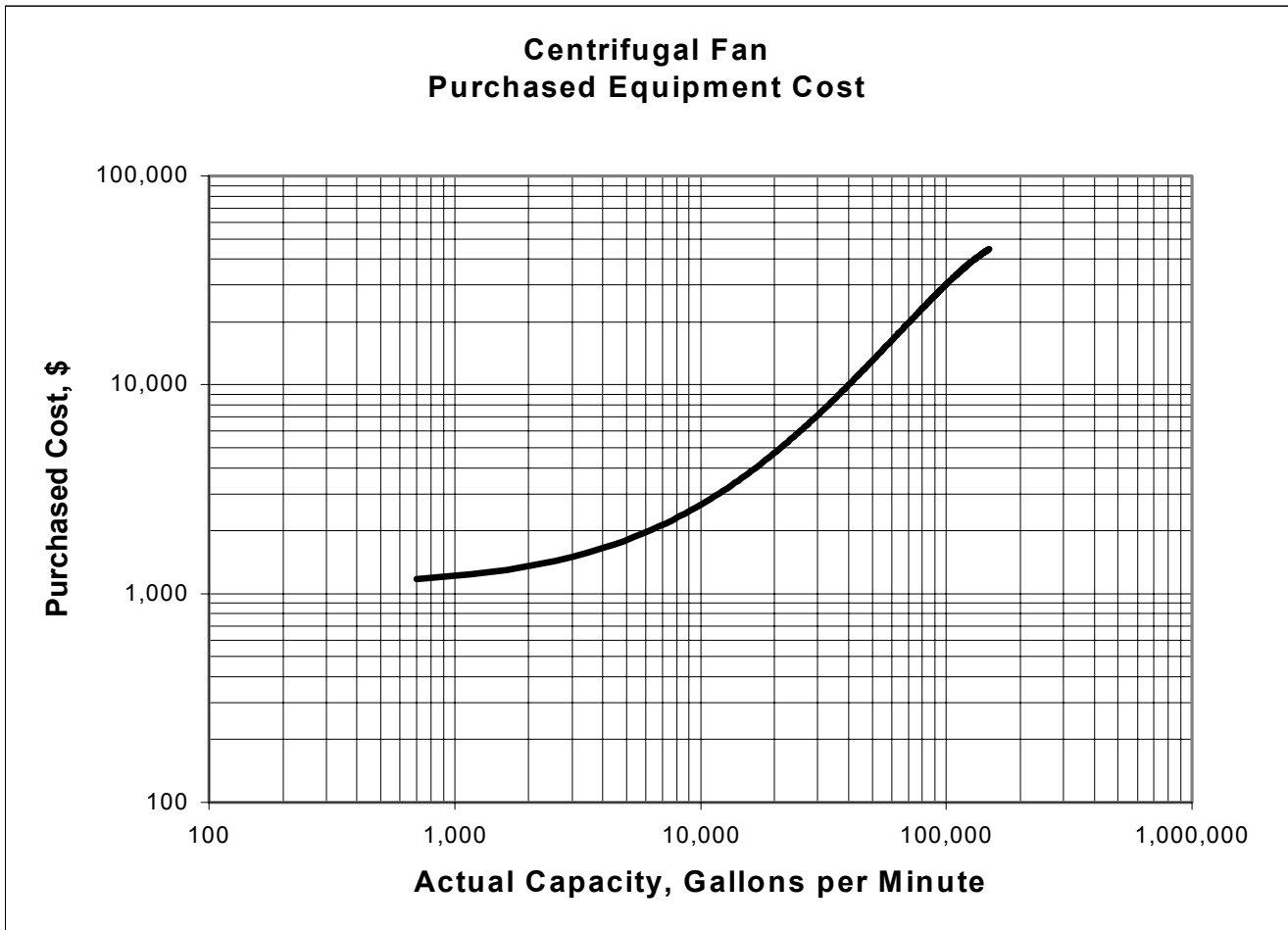
1st Quarter 1998 Dollars

Material: Carbon Steel

Power: 1.5 - 300 Horsepower

Speed: 1800 RPM

Exit Pressure: 6 In H₂O



Rotary Blower

Description: This general-purpose blower includes inlet and discharge silencers. The casing of the rotary blower is cast iron and the impellers are ductile iron.

Design Basis:

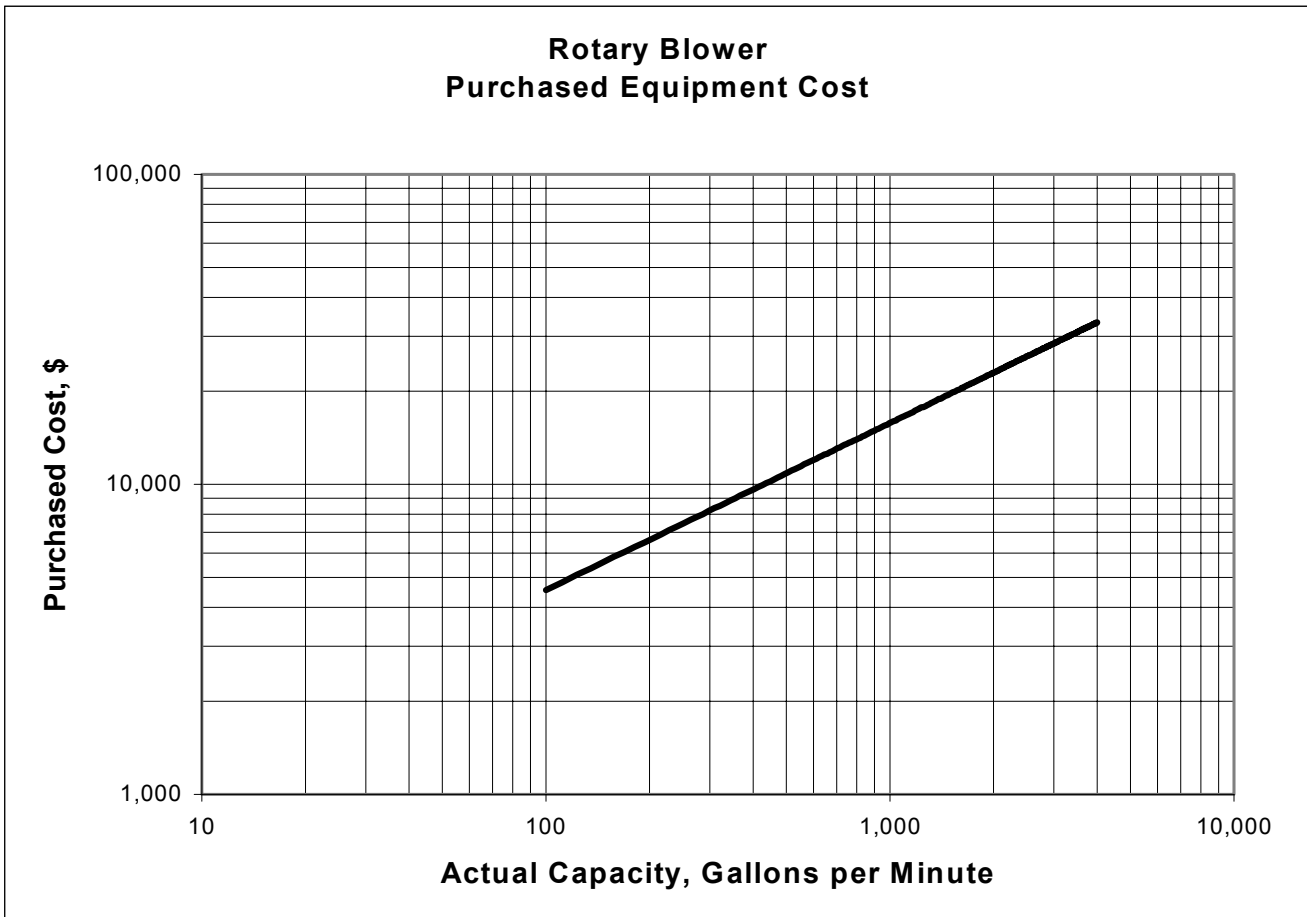
1st Quarter 1998 Dollars

Material: Carbon Steel

Power: 5 - 200 Horsepower

Speed: 1800 RPM

Exit Pressure: 8 psig



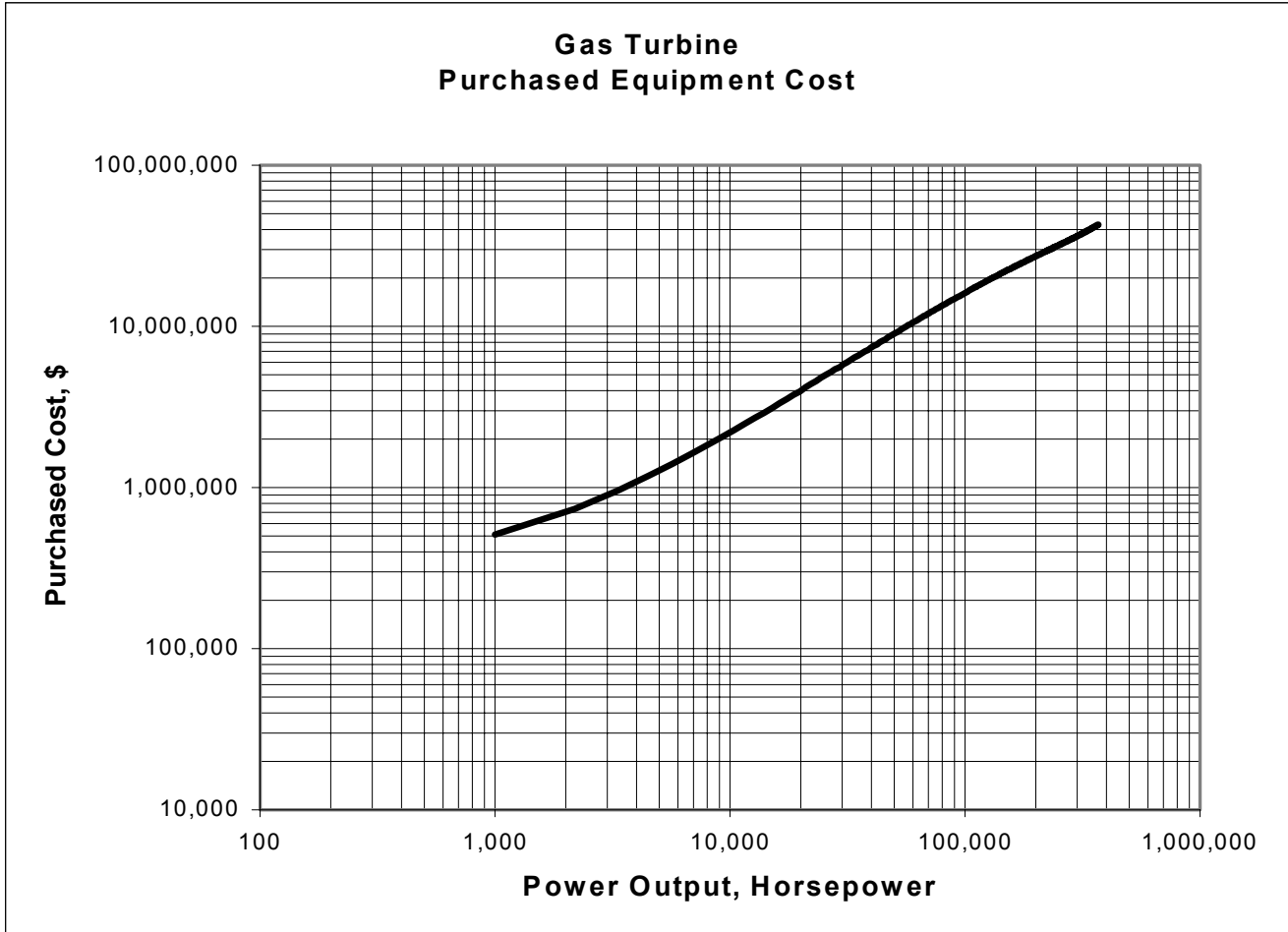
Gas Turbine

Description: Gas turbine includes fuel gas combustion chamber and multi-stage turbine expander.

Design Basis:

1st Quarter 1998 Dollars

Material: Carbon Steel



Steam Turbine – under 1000 Horsepower

Description: Steam turbine driver includes condenser and accessories.

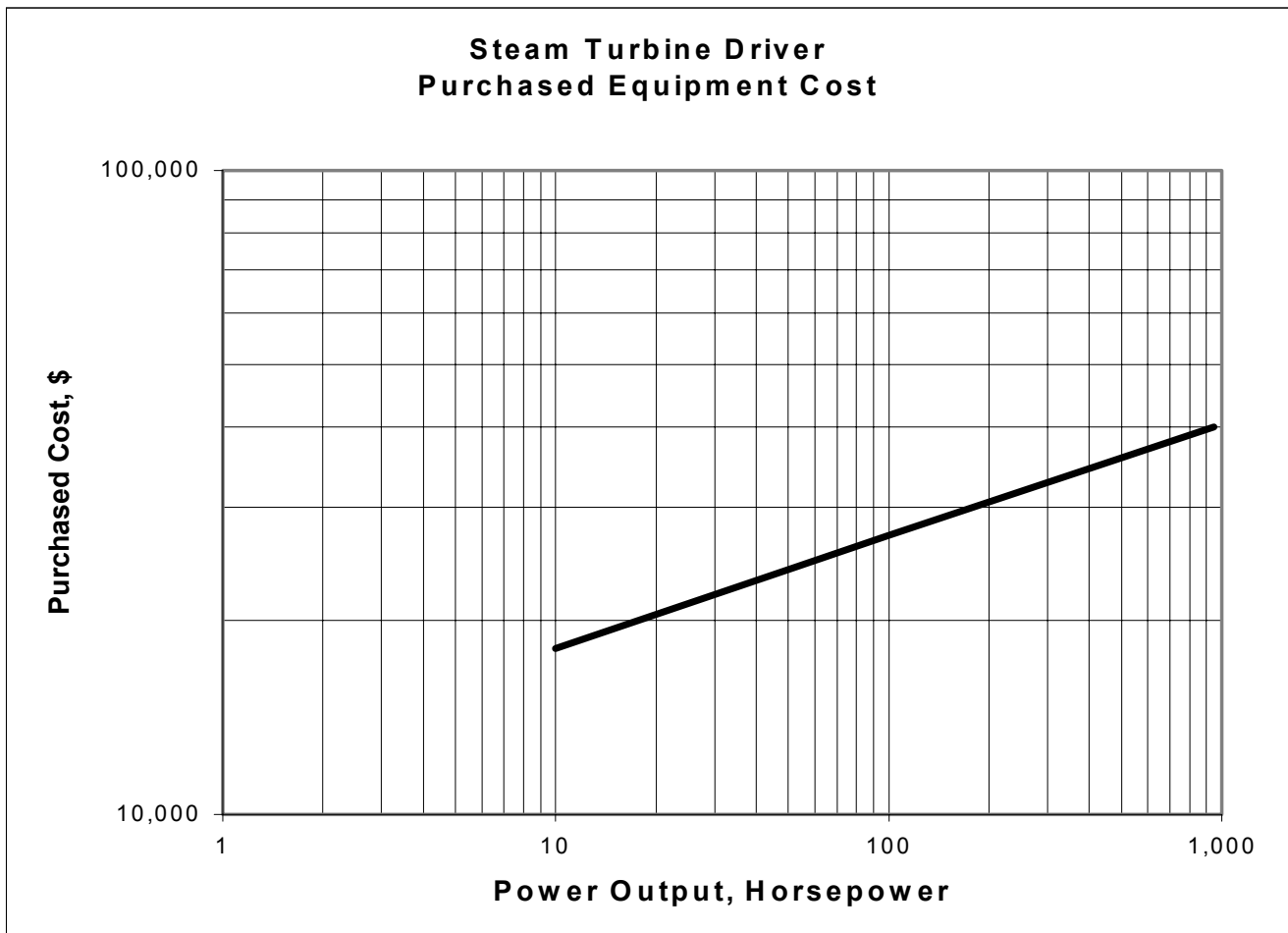
Design Basis:

1st Quarter 1998 Dollars

Material: Carbon Steel

Steam Pressure: 400 psig

Speed: 3600 RPM



Steam Turbine – over 1000 Horsepower

Description: Steam turbine driver includes condenser and accessories.

Design Basis:

1st Quarter 1998 Dollars

Material: Carbon Steel

Steam Pressure: 400 psig

Speed: 3600 RPM

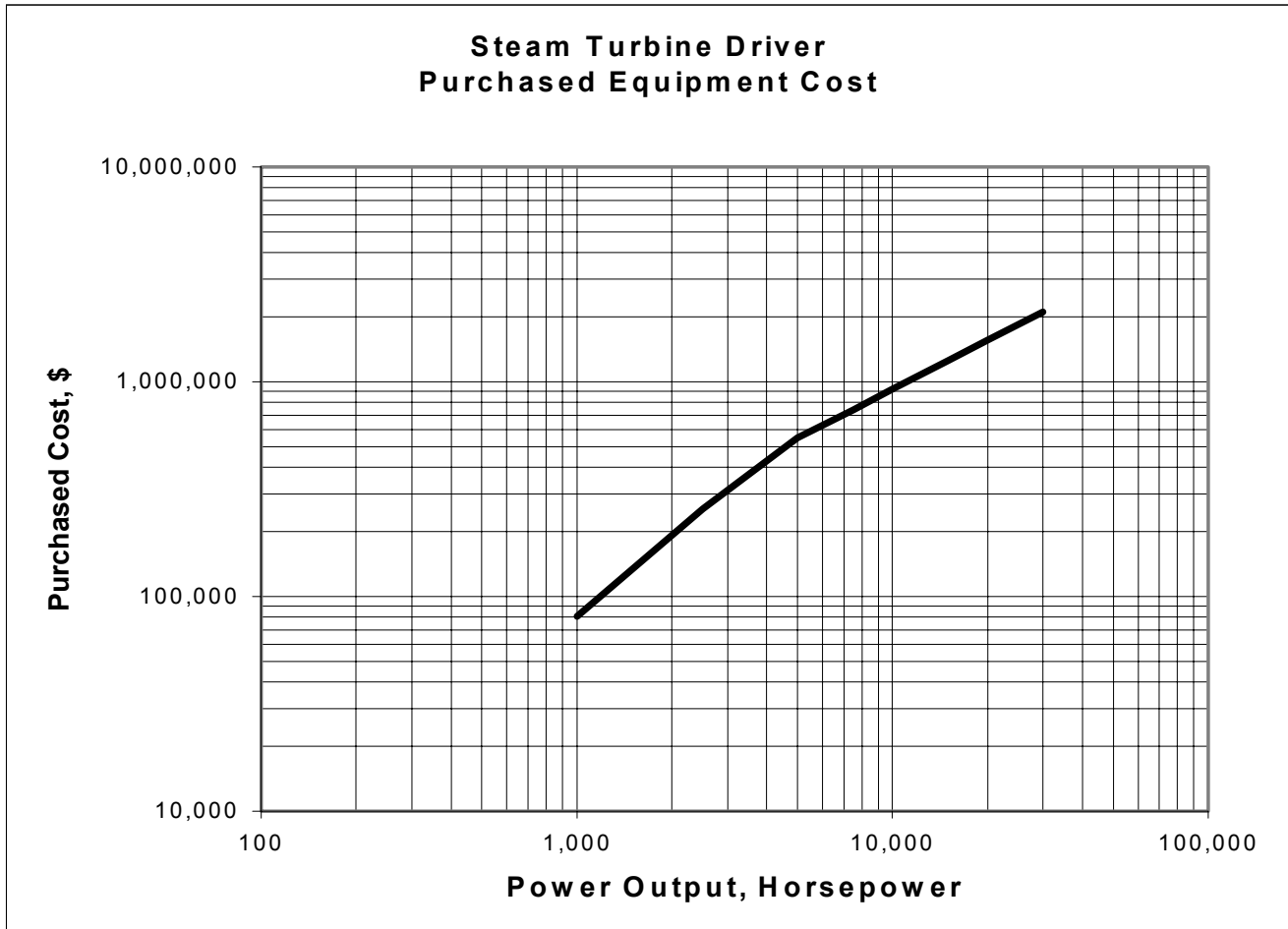


Table 2

Distributive Factors for Bulk Materials - Solids Handling Processes

| Temperature | | ≤400 °F | >400 °F |
|-------------------------|-----------------|----------------|-------------------|
| | | (%) | (%) |
| Foundations | <i>Material</i> | 4 | 5 |
| | <i>Labor</i> | 133 | 133 |
| Structural Steel | <i>Material</i> | 4 | 2 |
| | <i>Labor</i> | 50 | 100 |
| Buildings | <i>Material</i> | 2 | 2 |
| | <i>Labor</i> | 100 | 100 |
| Insulation | <i>Material</i> | --- | 1.5 |
| | <i>Labor</i> | --- | 150 |
| Instruments | <i>Material</i> | 6 | 6 |
| | <i>Labor</i> | 10 | 40 |
| Electrical | <i>Material</i> | 9 | 9 |
| | <i>Labor</i> | 75 | 75 |
| Piping | <i>Material</i> | 5 | 5 |
| | <i>Labor</i> | 50 | 50 |
| Painting | <i>Material</i> | 0.5 | 0.5 |
| | <i>Labor</i> | 300 | 300 |
| Miscellaneous | <i>Material</i> | 3 | 4 |
| | <i>Labor</i> | 80 | 80 |

Table 3

Distributive Factors for Bulk Materials – Solids - Gas Processes

| Temperature Pressure | | ≤ 400 °F | | > 400 °F | |
|-------------------------|-----------------|------------------------|---------------------|------------------------|---------------------|
| | | ≤ 150 psig (%) | > 150 psig (%) | ≤ 150 psig (%) | > 150 psig (%) |
| Foundations | <i>Material</i> | 5 | 6 | 6 | 6 |
| | <i>Labor</i> | 133 | 133 | 133 | 133 |
| Structural Steel | <i>Material</i> | 4 | 4 | 5 | 6 |
| | <i>Labor</i> | 100 | 100 | 50 | 50 |
| Buildings | <i>Material</i> | 2 | 2 | 5 | 4 |
| | <i>Labor</i> | 100 | 50 | 50 | 100 |
| Insulation | <i>Material</i> | 1 | 1 | 2 | 2 |
| | <i>Labor</i> | 150 | 150 | 150 | 150 |
| Instruments | <i>Material</i> | 2 | 7 | 7 | 8 |
| | <i>Labor</i> | 40 | 40 | 40 | 75 |
| Electrical | <i>Material</i> | 6 | 8 | 7 | 8 |
| | <i>Labor</i> | 75 | 75 | 75 | 75 |
| Piping | <i>Material</i> | 35 | 40 | 40 | 40 |
| | <i>Labor</i> | 50 | 50 | 50 | 50 |
| Painting | <i>Material</i> | 0.5 | 0.5 | 0.5 | 0.5 |
| | <i>Labor</i> | 300 | 300 | 300 | 300 |
| Miscellaneous | <i>Material</i> | 3.5 | 4 | 4 | 4.5 |
| | <i>Labor</i> | 80 | 80 | 80 | 80 |

Table 4

Distributive Factors for Bulk Materials - Liquid and Slurry Systems

| Pressure | | ≤ 150 psig (%) | >150 psig (%) |
|-------------------------|-----------------|------------------------|--------------------|
| Foundations | <i>Material</i> | 5 | 6 |
| | <i>Labor</i> | 133 | 133 |
| Structural Steel | <i>Material</i> | 4 | 5 |
| | <i>Labor</i> | 50 | 50 |
| Buildings | <i>Material</i> | 3 | 3 |
| | <i>Labor</i> | 100 | 100 |
| Insulation | <i>Material</i> | 1 | 3 |
| | <i>Labor</i> | 150 | 150 |
| Instruments | <i>Material</i> | 6 | 7 |
| | <i>Labor</i> | 40 | 40 |
| Electrical | <i>Material</i> | 8 | 9 |
| | <i>Labor</i> | 75 | 75 |
| Piping | <i>Material</i> | 30 | 35 |
| | <i>Labor</i> | 50 | 50 |
| Painting | <i>Material</i> | 0.5 | 0.5 |
| | <i>Labor</i> | 300 | 300 |
| Miscellaneous | <i>Material</i> | 4 | 5 |
| | <i>Labor</i> | 80 | 80 |

Table 5

Distributive Factors for Bulk Materials - Gas Processes

| Temperature Pressure | | ≤ 400 °F | | > 400 °F | |
|-------------------------|-----------------|------------------------|---------------------|------------------------|---------------------|
| | | ≤ 150 psig (%) | > 150 psig (%) | ≤ 150 psig (%) | > 150 psig (%) |
| Foundations | <i>Material</i> | 5 | 6 | 6 | 5 |
| | <i>Labor</i> | 133 | 133 | 133 | 133 |
| Structural Steel | <i>Material</i> | 5 | 5 | 5 | 6 |
| | <i>Labor</i> | 50 | 50 | 50 | 50 |
| Buildings | <i>Material</i> | 3 | 3 | 3 | 4 |
| | <i>Labor</i> | 100 | 100 | 100 | 100 |
| Insulation | <i>Material</i> | 1 | 1 | 2 | 3 |
| | <i>Labor</i> | 150 | 150 | 150 | 150 |
| Instruments | <i>Material</i> | 6 | 7 | 7 | 7 |
| | <i>Labor</i> | 40 | 40 | 75 | 40 |
| Electrical | <i>Material</i> | 8 | 9 | 6 | 9 |
| | <i>Labor</i> | 75 | 75 | 40 | 75 |
| Piping | <i>Material</i> | 45 | 40 | 40 | 40 |
| | <i>Labor</i> | 50 | 50 | 50 | 50 |
| Painting | <i>Material</i> | 0.5 | 0.5 | 0.5 | 0.5 |
| | <i>Labor</i> | 300 | 300 | 300 | 300 |
| Miscellaneous | <i>Material</i> | 3 | 4 | 4 | 5 |
| | <i>Labor</i> | 80 | 80 | 80 | 80 |

Table 6

Distributive Labor Factors for Setting Equipment

| Equipment Type | Factor (%) | Equipment Type | Factor (%) |
|-----------------------|-------------------|------------------------|-------------------|
| Absorber | 20 | Hammermill | 25 |
| Ammonia Still | 20 | Heater | 20 |
| Ball Mill | 30 | Heat Exchanger | 20 |
| Briquetting machine | 25 | Lime Leg | 15 |
| Centrifuge | 20 | Methanator (catalytic) | 30 |
| Clarifier | 15 | Mixer | 20 |
| Coke Cutter | 15 | Precipitator | 25 |
| Coke Drum | 15 | Regenerator (packed) | 20 |
| Condenser | 20 | Retort | 30 |
| Conditioner | 20 | Rotoclone | 25 |
| Cooler | 20 | Screen | 20 |
| Crusher | 30 | Scrubber (water) | 15 |
| Cyclone | 20 | Settler | 15 |
| Decanter | 15 | Shift converter | 25 |
| Distillation column | 30 | Splitter | 15 |
| Evaporator | 20 | Storage Tank | 20 |
| Filter | 15 | Stripper | 20 |
| Fractionator | 25 | Tank | 20 |
| Furnace | 30 | Vaporizer | 20 |
| Gasifier | 30 | | |

Table 7

Factors for Converting Carbon Steel to Equivalent Alloy Costs

| Material | Pumps, etc. | Other Equipment |
|---------------------------|--------------------|------------------------|
| All Carbon Steel | 1.00 | 1.00 |
| Stainless Steel, Type 410 | 1.43 | 2.00 |
| Stainless Steel, Type 304 | 1.70 | 2.80 |
| Stainless Steel, Type 316 | 1.80 | 2.90 |
| Stainless Steel, Type 310 | 2.00 | 3.33 |
| Rubber-lined Steel | 1.43 | 1.25 |
| Bronze | 1.54 | |
| Monel | 3.33 | |

| Material | Heat Exchangers |
|---|------------------------|
| Carbon Steel Shell and Tubes | 1.00 |
| Carbon Steel Shell, Aluminum Tubes | 1.25 |
| Carbon Steel Shell, Monel Tubes | 2.08 |
| Carbon Steel Shell, 304 Stainless Steel Tubes | 1.67 |
| 304 Stainless Steel Shell and Tubes | 2.86 |

Cost Indexes

Cost indexes are used to update costs from the base time, in this case First Quarter 1998 dollars, to the present time of the estimate. Cost indexes are used to give a general estimate, but can not take into account all factors. Some limitations of cost indexes include:³

1. Accuracy is very limited. Two Indexes may yield much different answers.
2. Cost indexes are based on averages. Specific cases may be much different from the average.
3. At best, 10% accuracy can be expected for periods up to 5 years.
4. For periods over 10 years, indexes are suitable only for order of magnitude estimates.

The most common indexes are Engineering News-Record Construction Cost Index, Table 8, (published in the *Engineering News-Record*), Marshall and Swift Equipment Cost Indexes, Table 9, (published in *Chemical Engineering*), Nelson-Farrar Refinery Construction Cost Index, Table 10, (published in the *Oil and Gas Journal*) and the Chemical Engineering Plant Cost Index, Table 11, (published in *Chemical Engineering*). Annual averages for each of these indexes are included in this report.

The Marshall and Swift Equipment Cost Indexes are divided into two categories, the all-industry equipment index and the process-industry equipment index. The indexes take into consideration the cost of machinery and major equipment plus costs for installation, fixtures, tools, office furniture, and other minor equipment. The Engineering News-Record Construction Cost Index shows the variation in the labor rates and materials costs for industrial construction. The Nelson-Farrar Refinery Construction Cost Index uses construction costs in the petroleum industry as the basis. The Chemical Engineering Plant Cost Index uses construction costs for chemical plants as the basis.

Two cost indexes, the Marshall and Swift equipment cost indexes and the Chemical Engineering plant cost indexes, give very similar results and are recommended for use with process-equipment estimates and chemical-plant investment estimates. The Engineering News-Record construction cost index, relative with time, has increased much more rapidly than the other two because it does not include a productivity improvement factor. Similarly, the Nelson-Farrar refinery construction index has shown a very large increase with time and should be used with caution and only for refinery construction.⁴

³ Humphreys, Dr. Kenneth K. PE CCE, "Preliminary Capital and Operating Cost Estimating (for the Process and Utility Industries)," course notes.

⁴ Peters, Max S. and Klaus D. Timmerhaus, "Plant Design and Economics for Chemical Engineers" McGraw-Hill, Inc. 1991.

Table 8

Engineering News Record Construction Cost Index
Published in the *Engineering News-Record*

| Year | Annual Average |
|-------------|-----------------------|
| 1913 | 100 |
| 1960 | 824 |
| 1965 | 971 |
| 1970 | 1381 |
| 1975 | 2212 |
| 1980 | 3237 |
| 1985 | 4195 |
| 1990 | 4732 |
| 1995 | 5471 |
| 1996 | 5620 |
| 1997 | 5825 |
| 1998 | 5920 |
| 1999 | 6060 |
| 2000 | 6222 |
| 2001 | |
| January | 6281 |
| February | 6273 |
| March | 6280 |
| April | 6286 |
| May | 6288 |

Table 9

Marshall and Swift Installed-Equipment Index
 Published in *Chemical Engineering*

| Year | Annual Average | |
|-------------|----------------|------------------|
| | All Industry | Process Industry |
| 1926 | 100 | 100 |
| 1964 | 242 | 241 |
| 1965 | 245 | 244 |
| 1970 | 303 | 301 |
| 1975 | 444 | 452 |
| 1980 | 560 | 675 |
| 1985 | 790 | 813 |
| 1990 | 915 | 935 |
| 1995 | 1027.5 | 1037.4 |
| 1996 | 1039.2 | 1051.3 |
| 1997 | 1056.8 | 1068.3 |
| 1998 | 1061.9 | 1075.9 |
| 1st Quarter | 1061.2 | 1074.6 |
| 2nd Quarter | 1061.8 | 1075.2 |
| 3rd Quarter | 1062.4 | 1077.2 |
| 4th Quarter | 1062.3 | 1076.6 |
| 1999 | 1068.3 | 1083.1 |
| 1st Quarter | 1062.7 | 1078.8 |
| 2nd Quarter | 1065.0 | 1080.7 |
| 3rd Quarter | 1069.9 | 1084.0 |
| 4th Quarter | 1075.6 | 1088.7 |
| 2000 | 1089.0 | 1102.7 |
| 1st Quarter | 1080.6 | 1093.5 |
| 2nd Quarter | 1089.0 | 1102.2 |
| 3rd Quarter | 1092.0 | 1106.3 |
| 4th Quarter | 1094.5 | 1108.7 |
| 2001 | | |
| 1st Quarter | 1092.8 | 1106.9 |

Table 10

Nelson-Farrar Refinery Construction Index
 Published in the *Oil and Gas Journal*

| Year | Annual Average | Pumps, Compressors, etc | Heat Exchangers | Misc. Equipment Average |
|-------------|----------------|-------------------------|-----------------|-------------------------|
| 1946 | 100 | | | |
| 1964 | 252 | | | |
| 1965 | 261 | | | |
| 1970 | 365 | | | |
| 1975 | 576 | | | |
| 1980 | 823 | 777.3 | 618.7 | 578.1 |
| 1985 | 1074 | 969.9 | 520 | 673.4 |
| 1990 | 1225.7 | 1125.6 | 755.7 | 797.5 |
| 1995 | 1392.1 | 1316.7 | 758.6 | 879.5 |
| 1996 | 1418.9 | 1354.5 | 793.3 | 903.5 |
| 1997 | 1449.2 | 1383.9 | 773.6 | 910.5 |
| 1998 | 1477.6 | 1406.7 | 841.1 | 933.2 |
| 1999 | 1497.2 | 1433.5 | 715.8 | 920.3 |
| 2000 | 1542.7 | 1456.4 | 662.2 | 917.8 |
| 2001 | | | | |
| January | 1565.9 | 1473.2 | 722.7 | 936.2 |
| February | 1563.6 | 1478.9 | 722.7 | 937.1 |

Table 11

Chemical Engineering Plant Cost Index
Published in *Chemical Engineering*

| Year | Annual Average |
|----------------|-----------------------|
| 1957-59 | 100 |
| 1964 | 103 |
| 1965 | 104 |
| 1970 | 126 |
| 1975 | 182 |
| 1980 | 261 |
| 1985 | 325 |
| 1990 | 357.6 |
| 1995 | 381.1 |
| 1996 | 381.8 |
| 1997 | 386.5 |
| 1998 | 389.5 |
| 1999 | 390.6 |
| 2000 | 394.1 |
| 2001 | |
| January | 395.4 |

Appendix A

The following is an example of the usage of the cost curves and tables to estimate the installed cost of a 5,000 square foot gas-gas shell and tube heat exchanger with a design temperature of 650°F and a design pressure of 150 psig.

From the chart on page 16, the estimated purchased equipment cost is \$62,000. From Table 6, the factor for setting a heat exchanger is 20%. Column 3 of Table 5 is used to estimate the bulk material and labor costs.

| | | |
|-----------------------|-------------------------|-----------|
| Bare cost: | | \$62,000 |
| Setting Cost: | $\$62,000 \times 0.2$ | \$12,400 |
| Bulk Installations: | | |
| Foundations | | |
| Material | $\$62,000 \times 0.06$ | \$3,720 |
| Labor | $\$3,720 \times 1.33$ | \$4,948 |
| Structural Steel | | |
| Material | $\$62,000 \times 0.05$ | \$3,100 |
| Labor | $\$3,100 \times 0.5$ | \$1,550 |
| Buildings | | |
| Material | $\$62,000 \times 0.03$ | \$1,860 |
| Labor | $\$1,860 \times 1.0$ | \$1,860 |
| Insulation | | |
| Material | $\$62,000 \times 0.02$ | \$1,240 |
| Labor | $\$1,240 \times 1.5$ | \$1,860 |
| Instruments | | |
| Material | $\$62,000 \times 0.07$ | \$4,340 |
| Labor | $\$4,340 \times 0.75$ | \$3,255 |
| Electrical | | |
| Material | $\$62,000 \times 0.06$ | \$3,720 |
| Labor | $\$3,720 \times 0.4$ | \$1,488 |
| Piping | | |
| Material | $\$62,000 \times 0.4$ | \$24,800 |
| Labor | $\$24,800 \times 0.5$ | \$12,400 |
| Painting | | |
| Material | $\$62,000 \times 0.005$ | \$310 |
| Labor | $\$310 \times 3.0$ | \$930 |
| Miscellaneous | | |
| Material | $\$62,000 \times 0.04$ | \$2,480 |
| Labor | $\$2,480 \times 0.8$ | \$1,984 |
| Total Installed Cost: | | \$150,245 |

From ICARUS-generated results (page 59):

| | |
|--------------------------|-----------|
| Purchased Equipment Cost | \$62,100 |
| Total Installed Cost | \$141,800 |

Appendix B

Vertical Vessels

1st Quarter 1998 dollars

| 15 psig | | | | | |
|-----------------|---------------|--------------------|-----------------------|-------------------------------|---------------------|
| Diameter (Feet) | Height (Feet) | Capacity (Gallons) | Total Weight (Pounds) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 2.5 | 2.7 | 100 | 1,000 | \$6,400 | \$51,800 |
| 3.0 | 4.7 | 250 | 1,400 | \$7,400 | \$61,000 |
| 4.0 | 5.3 | 500 | 2,000 | \$9,800 | \$68,400 |
| 4.0 | 8.0 | 750 | 2,700 | \$12,200 | \$89,700 |
| 5.0 | 6.8 | 1,000 | 3,000 | \$13,000 | \$96,000 |
| 6.0 | 9.5 | 2,000 | 4,200 | \$16,500 | \$122,300 |
| 7.0 | 10.4 | 3,000 | 5,200 | \$18,000 | \$132,300 |
| 7.0 | 13.9 | 4,000 | 6,300 | \$18,600 | \$135,100 |
| 8.0 | 13.3 | 5,000 | 7,100 | \$21,000 | \$139,700 |

| 150 psig | | | | | |
|-----------------|---------------|--------------------|-----------------------|-------------------------------|---------------------|
| Diameter (Feet) | Height (Feet) | Capacity (Gallons) | Total Weight (Pounds) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 2.5 | 2.7 | 100 | 1,300 | \$7,000 | \$48,800 |
| 3.0 | 4.7 | 250 | 1,800 | \$8,300 | \$52,500 |
| 4.0 | 5.3 | 500 | 2,800 | \$11,300 | \$60,900 |
| 4.0 | 8.0 | 750 | 3,600 | \$13,700 | \$76,900 |
| 5.0 | 6.8 | 1,000 | 4,500 | \$15,600 | \$84,800 |
| 6.0 | 9.5 | 2,000 | 7,000 | \$20,900 | \$100,700 |
| 7.0 | 10.4 | 3,000 | 9,600 | \$24,200 | \$112,800 |
| 7.0 | 13.9 | 4,000 | 11,400 | \$24,900 | \$115,800 |
| 8.0 | 13.3 | 5,000 | 14,200 | \$30,500 | \$124,000 |

Horizontal Vessels

1st Quarter 1998 dollars

| 15 psig | | | | | |
|------------------------|----------------------|---------------------------|------------------------------|--------------------------------------|----------------------------|
| Diameter (Feet) | Length (Feet) | Capacity (Gallons) | Total Weight (Pounds) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 2.0 | 4.3 | 100 | 1,100 | \$5,700 | \$51,900 |
| 2.5 | 6.8 | 250 | 1,500 | \$7,400 | \$62,200 |
| 3.0 | 9.5 | 500 | 2,200 | \$8,900 | \$79,600 |
| 4.0 | 8.0 | 750 | 2,600 | \$10,200 | \$81,600 |
| 4.0 | 10.6 | 1,000 | 3,000 | \$11,200 | \$88,500 |
| 6.0 | 14.2 | 3,000 | 5,600 | \$17,500 | \$24,600 |
| 7.0 | 17.4 | 5,000 | 7,600 | \$21,800 | \$32,300 |
| 8.0 | 18.6 | 7,000 | 9,400 | \$24,800 | \$144,800 |
| 9.0 | 21.0 | 10,000 | 11,500 | \$29,500 | \$153,100 |
| 11.0 | 35.2 | 25,000 | 21,500 | \$40,100 | \$202,600 |
| 14.0 | 43.4 | 50,000 | 33,300 | \$58,200 | \$251,500 |
| 14.5 | 60.7 | 75,000 | 47,000 | \$76,400 | \$304,900 |
| 14.5 | 81.0 | 100,000 | 59,400 | \$94,800 | \$383,500 |

| 150 psig | | | | | |
|------------------------|----------------------|---------------------------|------------------------------|--------------------------------------|----------------------------|
| Diameter (Feet) | Length (Feet) | Capacity (Gallons) | Total Weight (Pounds) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 2.0 | 4.3 | 100 | 1,400 | \$6,300 | \$48,900 |
| 2.5 | 6.8 | 250 | 1,800 | \$8,000 | \$53,200 |
| 3.0 | 9.5 | 500 | 2,500 | \$9,700 | \$66,000 |
| 4.0 | 8.0 | 750 | 3,500 | \$12,000 | \$69,200 |
| 4.0 | 10.6 | 1,000 | 4,000 | \$13,100 | \$76,400 |
| 6.0 | 14.2 | 3,000 | 8,900 | \$23,500 | \$104,800 |
| 7.0 | 17.4 | 5,000 | 13,500 | \$32,100 | \$117,200 |
| 8.0 | 18.6 | 7,000 | 18,300 | \$39,900 | \$148,000 |
| 9.0 | 21.0 | 10,000 | 24,800 | \$51,800 | \$163,800 |
| 11.0 | 35.2 | 25,000 | 54,100 | \$90,300 | \$267,800 |
| 14.0 | 43.4 | 50,000 | 101,900 | \$160,400 | \$373,200 |
| 14.5 | 60.7 | 75,000 | 155,000 | \$230,300 | \$482,200 |
| 14.5 | 81.0 | 100,000 | 198,700 | \$285,700 | \$606,700 |

Storage Tanks

1st Quarter 1998 dollars

| Diameter (Feet) | Height (Feet) | Total Weight (Pounds) | Capacity (Gallons) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|----------------------|---------------|-----------------------|--------------------|-------------------------------|---------------------|
| Floating Roof | | | | | |
| 17.0 | 32.0 | 41,300 | 50,000 | \$118,000 | \$163,400 |
| 20.0 | 32.0 | 46,700 | 75,000 | \$128,200 | \$180,700 |
| 24.0 | 32.0 | 55,000 | 100,000 | \$143,200 | \$205,100 |
| 37.0 | 32.0 | 89,300 | 250,000 | \$197,700 | \$250,000 |
| 47.0 | 40.0 | 142,400 | 500,000 | \$267,800 | \$332,400 |
| 57.0 | 40.0 | 195,000 | 750,000 | \$335,700 | \$411,700 |
| 66.0 | 40.0 | 245,700 | 1,000,000 | \$396,600 | \$480,200 |
| 134.0 | 48.0 | 858,900 | 5,000,000 | \$1,061,200 | \$1,250,900 |
| 175.0 | 56.0 | 2,219,100 | 10,000,000 | \$2,273,000 | \$2,564,300 |
| Cone Roof | | | | | |
| 17.0 | 32.0 | 21,000 | 50,000 | \$42,400 | \$87,800 |
| 20.0 | 32.0 | 26,400 | 75,000 | \$48,900 | \$101,400 |
| 24.0 | 32.0 | 34,800 | 100,000 | \$59,200 | \$121,100 |
| 37.0 | 32.0 | 69,400 | 250,000 | \$98,600 | \$150,900 |
| 47.0 | 40.0 | 123,100 | 500,000 | \$157,800 | \$222,400 |
| 57.0 | 40.0 | 176,400 | 750,000 | \$214,800 | \$296,800 |
| 66.0 | 40.0 | 228,000 | 1,000,000 | \$266,100 | \$349,700 |
| 134.0 | 48.0 | 853,600 | 5,000,000 | \$864,300 | \$1,054,000 |
| 175.0 | 56.0 | 2,226,100 | 10,000,000 | \$2,040,700 | \$2,332,000 |

Valve Tray Columns
1st Quarter 1998 dollars

| Diameter (ft) | Number of Trays | 15 psig | | 150 psig | |
|---------------|-----------------|-------------------------------|---------------------|-------------------------------|---------------------|
| | | Purchased Equipment Cost (\$) | Installed Cost (\$) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 5 | 2 | \$30,600 | \$159,500 | \$35,200 | \$161,300 |
| 5 | 6 | \$42,300 | \$175,700 | \$50,000 | \$180,600 |
| 5 | 10 | \$49,000 | \$192,100 | \$57,300 | \$192,000 |
| 5 | 14 | \$56,100 | \$203,400 | \$67,300 | \$206,200 |
| 5 | 20 | \$69,700 | \$225,900 | \$84,700 | \$232,500 |
| 5 | 26 | \$82,300 | \$246,200 | \$95,800 | \$251,000 |
| 5 | 34 | \$99,800 | \$285,800 | \$118,500 | \$285,300 |
| 5 | 40 | \$115,200 | \$310,300 | \$134,500 | \$315,300 |
| 5 | 46 | \$132,000 | \$335,200 | \$145,000 | \$332,700 |
| 5 | 52 | \$164,900 | \$378,000 | \$185,200 | \$382,600 |
| 5 | 60 | \$204,900 | \$429,700 | \$226,000 | \$435,000 |
| 10 | 2 | \$62,500 | \$249,000 | \$89,600 | \$269,500 |
| 10 | 6 | \$88,400 | \$282,100 | \$122,800 | \$309,900 |
| 10 | 10 | \$109,700 | \$311,100 | \$151,800 | \$346,700 |
| 10 | 14 | \$128,600 | \$349,700 | \$180,700 | \$386,000 |
| 10 | 20 | \$160,400 | \$394,800 | \$220,900 | \$443,400 |
| 10 | 26 | \$188,500 | \$436,200 | \$254,200 | \$492,200 |
| 10 | 34 | \$233,600 | \$498,700 | \$312,500 | \$565,800 |
| 10 | 40 | \$263,800 | \$558,700 | \$356,300 | \$624,000 |
| 10 | 46 | \$297,100 | \$605,000 | \$391,300 | \$678,300 |
| 10 | 52 | \$343,000 | \$666,100 | \$450,000 | \$754,600 |
| 10 | 60 | \$388,400 | \$727,700 | \$501,900 | \$822,100 |
| 15 | 2 | \$119,900 | \$396,200 | \$221,500 | \$475,100 |
| 15 | 6 | \$171,000 | \$469,300 | \$293,000 | \$559,000 |
| 15 | 10 | \$225,700 | \$539,500 | \$364,500 | \$652,400 |
| 15 | 14 | \$262,500 | \$587,100 | \$425,800 | \$725,200 |
| 15 | 20 | \$332,400 | \$677,700 | \$522,400 | \$843,700 |
| 15 | 26 | \$387,000 | \$767,500 | \$600,200 | \$943,900 |
| 15 | 34 | \$473,900 | \$878,600 | \$722,100 | \$1,089,500 |
| 15 | 40 | \$538,600 | \$958,700 | \$808,900 | \$1,191,500 |
| 15 | 46 | \$620,900 | \$1,061,600 | \$907,000 | \$1,314,300 |
| 15 | 52 | \$689,200 | \$1,147,900 | \$997,700 | \$1,423,400 |
| 15 | 60 | \$786,500 | \$1,269,800 | \$1,145,800 | \$1,594,100 |
| 20 | 2 | \$174,900 | \$574,900 | \$402,000 | \$806,800 |
| 20 | 6 | \$247,900 | \$674,400 | \$517,300 | \$945,200 |
| 20 | 10 | \$359,400 | \$815,300 | \$605,100 | \$1,064,600 |
| 20 | 14 | \$421,000 | \$892,200 | \$715,700 | \$1,190,500 |
| 20 | 20 | \$508,000 | \$1,023,200 | \$857,000 | \$1,363,200 |
| 20 | 26 | \$585,300 | \$1,114,100 | \$993,600 | \$1,520,800 |
| 20 | 34 | \$726,300 | \$1,285,400 | \$1,203,000 | \$1,762,200 |
| 20 | 40 | \$834,300 | \$1,421,000 | \$1,347,900 | \$1,931,400 |
| 20 | 46 | \$952,800 | \$1,560,900 | \$1,526,400 | \$2,138,200 |
| 20 | 52 | \$1,051,100 | \$1,682,200 | \$1,669,100 | \$2,314,600 |
| 20 | 60 | \$1,195,500 | \$1,856,100 | \$1,892,600 | \$2,568,700 |

Sieve Tray Columns
1st Quarter 1998 dollars

| Diameter (ft) | Number of Trays | Tangent/Tangent Height | 15 psig | | 150 psig | |
|---------------|-----------------|------------------------|-------------------------------|---------------------|-------------------------------|---------------------|
| | | | Purchased Equipment Cost (\$) | Installed Cost (\$) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 5 | 2 | 17 | \$30,000 | \$158,900 | \$34,700 | \$160,800 |
| 5 | 6 | 25 | \$41,200 | \$174,600 | \$48,900 | \$179,500 |
| 5 | 10 | 33 | \$47,500 | \$190,600 | \$55,800 | \$190,500 |
| 5 | 14 | 41 | \$54,200 | \$201,400 | \$65,400 | \$204,300 |
| 5 | 20 | 53 | \$67,400 | \$223,500 | \$82,300 | \$230,000 |
| 5 | 26 | 65 | \$79,500 | \$243,200 | \$93,000 | \$248,100 |
| 5 | 34 | 81 | \$96,300 | \$282,200 | \$115,000 | \$281,700 |
| 5 | 40 | 93 | \$111,000 | \$305,900 | \$130,300 | \$310,900 |
| 5 | 46 | 105 | \$126,800 | \$329,700 | \$140,200 | \$327,700 |
| 5 | 52 | 117 | \$159,500 | \$372,400 | \$179,800 | \$377,000 |
| 5 | 60 | 133 | \$203,300 | \$428,100 | \$218,900 | \$427,500 |
| 10 | 2 | 17 | \$60,600 | \$247,100 | \$87,700 | \$267,600 |
| 10 | 6 | 25 | \$84,600 | \$278,200 | \$119,000 | \$306,100 |
| 10 | 10 | 33 | \$104,500 | \$305,800 | \$146,500 | \$341,300 |
| 10 | 14 | 41 | \$122,100 | \$343,100 | \$174,200 | \$379,400 |
| 10 | 20 | 53 | \$152,300 | \$386,500 | \$212,800 | \$435,000 |
| 10 | 26 | 65 | \$178,900 | \$426,300 | \$244,700 | \$482,300 |
| 10 | 34 | 81 | \$221,100 | \$485,700 | \$300,000 | \$552,800 |
| 10 | 40 | 93 | \$248,400 | \$542,700 | \$341,500 | \$608,600 |
| 10 | 46 | 105 | \$280,200 | \$587,400 | \$374,400 | \$661,000 |
| 10 | 52 | 117 | \$324,600 | \$647,000 | \$430,900 | \$735,100 |
| 10 | 60 | 133 | \$366,300 | \$704,700 | \$479,800 | \$798,100 |
| 15 | 2 | 17 | \$115,900 | \$392,100 | \$217,600 | \$471,200 |
| 15 | 6 | 25 | \$163,200 | \$461,400 | \$285,200 | \$551,100 |
| 15 | 10 | 33 | \$214,900 | \$528,600 | \$353,700 | \$641,300 |
| 15 | 14 | 41 | \$249,100 | \$573,400 | \$412,300 | \$711,400 |
| 15 | 20 | 53 | \$315,600 | \$660,400 | \$505,600 | \$826,600 |
| 15 | 26 | 65 | \$367,100 | \$746,900 | \$580,400 | \$923,600 |
| 15 | 34 | 81 | \$446,800 | \$850,800 | \$696,200 | \$1,063,100 |
| 15 | 40 | 93 | \$509,300 | \$928,700 | \$778,400 | \$1,160,300 |
| 15 | 46 | 105 | \$585,800 | \$1,025,700 | \$871,800 | \$1,278,100 |
| 15 | 52 | 117 | \$645,700 | \$1,103,400 | \$958,000 | \$1,382,600 |
| 15 | 60 | 133 | \$739,400 | \$1,221,700 | \$1,100,000 | \$1,546,900 |
| 20 | 2 | 17 | \$168,200 | \$568,100 | \$395,400 | \$800,100 |
| 20 | 6 | 25 | \$234,600 | \$661,000 | \$504,000 | \$931,700 |
| 20 | 10 | 33 | \$341,200 | \$796,700 | \$586,800 | \$1,046,100 |
| 20 | 14 | 41 | \$398,500 | \$869,100 | \$693,100 | \$1,167,600 |
| 20 | 20 | 53 | \$479,700 | \$994,300 | \$828,800 | \$1,334,500 |
| 20 | 26 | 65 | \$551,900 | \$1,080,000 | \$960,300 | \$1,486,500 |
| 20 | 34 | 81 | \$681,100 | \$1,239,200 | \$1,159,400 | \$1,717,400 |
| 20 | 40 | 93 | \$781,300 | \$1,365,200 | \$1,296,600 | \$1,876,900 |
| 20 | 46 | 105 | \$892,200 | \$1,498,500 | \$1,467,400 | \$2,075,600 |
| 20 | 52 | 117 | \$988,200 | \$1,624,000 | \$1,602,400 | \$2,246,100 |
| 20 | 60 | 133 | \$1,120,200 | \$1,778,700 | \$1,815,600 | \$2,489,600 |

Packed Columns

1st Quarter 1998 dollars

| Diameter (Feet) | Tangent/ Tangent Height (Feet) | Packed Height (Feet) | Number of Sections | 15 psig | | 150 psig | |
|--------------------|---|----------------------------|--------------------------|-------------------------------------|------------------------|-------------------------------------|------------------------|
| | | | | Purchased Equipment Cost (\$) | Installed Cost (\$) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 1 | 10 | 8 | 1 | \$6,700 | \$64,000 | \$6,600 | \$62,000 |
| 1 | 20 | 18 | 3 | \$8,700 | \$73,400 | \$9,000 | \$67,800 |
| 1.5 | 10 | 8 | 1 | \$10,300 | \$75,500 | \$11,300 | \$69,800 |
| 1.5 | 20 | 18 | 2 | \$13,900 | \$83,000 | \$15,400 | \$77,600 |
| 1.5 | 30 | 28 | 3 | \$16,600 | \$89,700 | \$18,700 | \$84,800 |
| 2 | 10 | 8 | 1 | \$12,900 | \$82,800 | \$13,900 | \$76,500 |
| 2 | 20 | 18 | 2 | \$16,900 | \$90,900 | \$18,500 | \$85,000 |
| 2 | 30 | 28 | 2 | \$18,600 | \$97,000 | \$20,100 | \$90,900 |
| 2 | 40 | 38 | 3 | \$21,500 | \$105,500 | \$23,600 | \$101,400 |
| 2.5 | 10 | 8 | 1 | \$14,700 | \$92,200 | \$15,400 | \$82,400 |
| 2.5 | 20 | 18 | 1 | \$16,700 | \$98,700 | \$17,600 | \$89,000 |
| 2.5 | 30 | 28 | 2 | \$22,400 | \$112,000 | \$23,800 | \$104,200 |
| 2.5 | 40 | 38 | 2 | \$23,200 | \$116,000 | \$24,600 | \$108,000 |
| 2.5 | 50 | 48 | 3 | \$30,000 | \$127,800 | \$31,800 | \$119,800 |
| 3 | 10 | 8 | 1 | \$16,200 | \$98,700 | \$17,200 | \$89,400 |
| 3 | 20 | 18 | 1 | \$21,900 | \$110,800 | \$23,500 | \$101,900 |
| 3 | 30 | 28 | 2 | \$24,300 | \$119,700 | \$25,900 | \$112,100 |
| 3 | 40 | 38 | 2 | \$26,500 | \$125,300 | \$29,200 | \$118,500 |
| 3 | 50 | 48 | 3 | \$31,200 | \$135,400 | \$34,700 | \$129,500 |
| 3 | 60 | 58 | 3 | \$35,400 | \$147,400 | \$37,500 | \$135,900 |
| 3.5 | 10 | 8 | 1 | \$20,600 | \$112,300 | \$23,100 | \$100,000 |
| 3.5 | 20 | 18 | 1 | \$26,400 | \$125,000 | \$30,600 | \$118,200 |
| 3.5 | 30 | 28 | 2 | \$30,400 | \$135,800 | \$35,000 | \$126,300 |
| 3.5 | 40 | 38 | 2 | \$31,500 | \$140,800 | \$36,300 | \$131,300 |
| 3.5 | 50 | 48 | 3 | \$38,700 | \$157,600 | \$45,000 | \$145,700 |
| 3.5 | 60 | 58 | 3 | \$43,400 | \$166,600 | \$48,000 | \$152,500 |
| 3.5 | 70 | 68 | 4 | \$48,400 | \$178,500 | \$57,600 | \$168,000 |

Shell and Tube Heat Exchangers

1st Quarter 1998 dollars

| Surface Area, (Square feet) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--|--|--------------------------------|
| 100 | \$13,200 | \$48,300 |
| 200 | \$13,600 | \$55,800 |
| 300 | \$14,500 | \$57,300 |
| 400 | \$16,100 | \$59,100 |
| 500 | \$16,200 | \$68,000 |
| 600 | \$16,600 | \$68,400 |
| 700 | \$18,000 | \$70,000 |
| 800 | \$18,400 | \$70,400 |
| 900 | \$20,300 | \$72,600 |
| 1000 | \$20,800 | \$73,100 |
| 2000 | \$31,900 | \$95,800 |
| 3000 | \$44,700 | \$109,600 |
| 4000 | \$53,900 | \$132,900 |
| 5000 | \$62,100 | \$141,800 |
| 6000 | \$70,800 | \$151,100 |
| 7000 | \$99,600 | \$203,500 |
| 8000 | \$107,900 | \$212,400 |
| 9000 | \$117,100 | \$222,100 |
| 10000 | \$124,200 | \$229,800 |
| 15000 | \$186,300 | \$321,500 |
| 20000 | \$248,400 | \$427,000 |
| 30000 | \$354,000 | \$573,900 |
| 40000 | \$479,100 | \$767,500 |
| 50000 | \$582,500 | \$953,000 |
| 60000 | \$708,300 | \$1,106,600 |
| 70000 | \$839,000 | \$1,425,600 |

Air Cooler1st Quarter 1998 dollars

| Surface Area, (Square feet) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--|--|--------------------------------|
| 100 | \$21,300 | \$47,600 |
| 200 | \$24,100 | \$51,800 |
| 300 | \$26,100 | \$54,800 |
| 400 | \$29,100 | \$58,100 |
| 500 | \$30,900 | \$59,900 |
| 600 | \$33,000 | \$62,000 |
| 700 | \$36,000 | \$65,300 |
| 800 | \$38,100 | \$67,400 |
| 900 | \$40,300 | \$69,900 |
| 1,000 | \$42,000 | \$71,600 |
| 2,000 | \$60,800 | \$94,100 |
| 4,000 | \$96,900 | \$144,700 |
| 6,000 | \$135,400 | \$184,700 |
| 8,000 | \$179,100 | \$239,000 |
| 10,000 | \$217,300 | \$278,200 |

Spiral Plate Heat Exchanger1st Quarter 1998 dollars

| Heat Transfer Area, (Square feet) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--|--|--------------------------------|
| 40 | \$6,700 | \$19,200 |
| 100 | \$9,100 | \$25,100 |
| 200 | \$13,200 | \$34,000 |
| 300 | \$21,100 | \$49,400 |
| 400 | \$25,500 | \$57,400 |
| 500 | \$29,900 | \$65,000 |
| 600 | \$34,400 | \$72,400 |
| 700 | \$42,600 | \$85,300 |
| 800 | \$35,500 | \$74,200 |
| 900 | \$40,000 | \$81,300 |
| 1,000 | \$44,700 | \$88,500 |
| 1,100 | \$49,600 | \$95,700 |
| 1,200 | \$54,700 | \$102,900 |
| 1,300 | \$60,100 | \$110,400 |

Furnace1st Quarter 1998 dollars

| Heat Duty (MMBTU per hour) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|---|--|--------------------------------|
| 2 | \$124,600 | \$96,300 |
| 10 | \$263,100 | \$355,100 |
| 25 | \$399,000 | \$518,600 |
| 50 | \$625,400 | \$771,100 |
| 100 | \$1,081,500 | \$1,272,800 |
| 200 | \$1,868,900 | \$2,641,500 |
| 300 | \$2,573,100 | \$3,534,400 |
| 400 | \$3,228,000 | \$4,354,800 |
| 500 | \$3,848,400 | \$5,126,000 |

Cooling Tower1st Quarter 1998 dollars

| Water Rate (Gallons/ minute) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|---|--|--------------------------------|
| 150 | \$4,000 | \$60,200 |
| 300 | \$6,500 | \$65,000 |
| 600 | \$11,400 | \$70,500 |
| 1,000 | \$18,000 | \$81,700 |
| 2,000 | \$34,400 | \$106,100 |
| 3,000 | \$50,900 | \$134,200 |
| 4,000 | \$67,100 | \$158,800 |
| 5,000 | \$83,200 | \$180,400 |
| 6,000 | \$99,200 | \$211,100 |

Package Steam Boiler1st Quarter 1998 dollars

| Capacity (Pound per hour) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--|--|--------------------------------|
| 10,000 | \$91,700 | \$283,100 |
| 25,000 | \$148,100 | \$368,900 |
| 50,000 | \$212,700 | \$468,900 |
| 100,000 | \$305,700 | \$607,300 |
| 150,000 | \$439,400 | \$783,600 |
| 200,000 | \$568,400 | \$920,600 |
| 250,000 | \$694,000 | \$1,109,100 |
| 300,000 | \$816,900 | \$1,238,600 |

Evaporator1st Quarter 1998 dollars

| Area (Square feet) | Vertical Tube | | Horizontal Tube | |
|-----------------------------------|--|------------------------------------|--|------------------------------------|
| | Purchased Equipment Cost (\$) | Installed Cost (\$) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 100 | \$62,600 | \$120,800 | \$34,500 | \$73,300 |
| 500 | \$151,600 | \$273,500 | \$81,100 | \$161,300 |
| 1,000 | \$221,900 | \$388,400 | \$117,100 | \$226,300 |
| 2,000 | \$324,700 | \$555,200 | \$169,000 | \$317,100 |
| 3,000 | \$405,700 | \$689,100 | \$209,500 | \$386,300 |
| 4,000 | \$475,200 | \$803,300 | \$244,100 | \$444,300 |
| 5,000 | \$537,100 | \$904,700 | \$274,400 | \$496,800 |
| 6,000 | \$593,700 | \$997,000 | \$302,600 | \$545,600 |
| 7,000 | | | \$328,300 | \$590,500 |
| 8,000 | | | \$352,400 | \$632,400 |
| 9,000 | | | \$375,100 | \$671,900 |
| 10,000 | | | \$396,600 | \$709,200 |

Crusher1st Quarter 1998 dollars

| Diameter (Inches) | Driver Power (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|------------------------------|--------------------------------------|--|--------------------------------|
| Gyratory Crusher | | | |
| 20 | 40 | \$29,300 | \$52,400 |
| 40 | 150 | \$253,600 | \$294,400 |
| 60 | 350 | \$698,200 | \$787,200 |
| 80 | 600 | \$1,400,900 | \$1,553,600 |
| 100 | 900 | \$2,415,500 | \$2,666,100 |
| 120 | 1250 | \$3,778,800 | \$4,171,200 |
| Rotary Crusher | | | |
| | 2 | \$2,300 | \$5,200 |
| | 4 | \$3,700 | \$6,800 |
| | 8 | \$6,100 | \$9,500 |
| | 12 | \$8,100 | \$11,800 |
| | 16 | \$9,900 | \$13,900 |
| | 20 | \$11,600 | \$15,800 |
| | 25 | \$13,600 | \$18,100 |
| Ring Granulator | | | |
| | 75 | \$23,400 | \$28,100 |
| | 125 | \$50,700 | \$58,000 |
| | 250 | \$75,900 | \$85,900 |
| | 600 | \$197,400 | \$218,700 |
| | 1000 | \$303,300 | \$335,600 |
| | 1250 | \$346,400 | \$382,200 |

Mill1st Quarter 1998 dollars

| Diameter/ Length (Inches) | Driver Power (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--|--------------------------------------|--|--------------------------------|
| Ball Mill | | | |
| 3/3 | 7.5 | \$25,100 | \$62,900 |
| 4/4 | 20 | \$57,500 | \$97,900 |
| 5/5 | 50 | \$109,100 | \$153,500 |
| 6/6 | 100 | \$182,900 | \$234,400 |
| | 200 | \$255,600 | \$311,700 |
| | 300 | \$411,300 | \$478,500 |
| | 400 | \$492,200 | \$573,100 |
| | 450 | \$585,200 | \$673,100 |
| Roller Mill | | | |
| | 30 | \$61,400 | \$76,900 |
| | 75 | \$107,500 | \$131,100 |
| | 150 | \$164,200 | \$197,000 |
| | 200 | \$195,800 | \$233,100 |
| | 250 | \$224,400 | \$265,800 |
| | 300 | \$250,900 | \$296,100 |
| | 350 | \$275,700 | \$324,400 |
| | 400 | \$299,100 | \$351,000 |

Dryers

1st Quarter 1998 dollars

| Area (Square feet) | Driver Power (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--------------------------------------|------------------------------|-------------------------------------|------------------------|
| Direct Contact Rotary Dryer | | | |
| 100 | | \$26,500 | \$42,400 |
| 400 | | \$99,500 | \$142,800 |
| 800 | | \$192,700 | \$264,800 |
| 1200 | | \$283,600 | \$380,800 |
| 1600 | | \$373,100 | \$493,400 |
| 2000 | | \$461,500 | \$603,500 |
| Single Atmospheric Drum Dryer | | | |
| 10 | 5 | \$53,900 | \$73,800 |
| 40 | 10 | \$125,800 | \$162,900 |
| 80 | 15 | \$192,300 | \$243,800 |
| 120 | 20 | \$246,500 | \$309,100 |
| 160 | 20 | \$293,900 | \$365,900 |
| 200 | 25 | \$337,100 | \$417,400 |
| Atmospheric Tray Batch Dryer | | | |
| 30 | | \$6,400 | \$10,900 |
| 60 | | \$8,400 | \$13,900 |
| 90 | | \$9,800 | \$16,000 |
| 120 | | \$10,900 | \$17,700 |
| 150 | | \$11,900 | \$19,200 |
| 180 | | \$12,800 | \$20,500 |
| 200 | | \$13,300 | \$21,300 |

Centrifuge

1st Quarter 1998 dollars

| Screen Diameter (Inches) | Driver Power (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--|---------------------------|-------------------------------|---------------------|
| Batch Bottom-Suspended Filtering Centrifuge | | | |
| 20 | 1.5 | \$10,100 | \$21,500 |
| 25 | 2 | \$11,900 | \$23,500 |
| 30 | 3 | \$13,600 | \$25,500 |
| 35 | 5 | \$15,300 | \$27,400 |
| 40 | 7.5 | \$16,900 | \$29,300 |
| 45 | 10 | \$18,400 | \$31,100 |
| 48 | 10 | \$19,300 | \$32,200 |
| Batch Top-Suspended Filtering Centrifuge | | | |
| 20 | 1.5 | \$12,000 | \$23,400 |
| 25 | 2 | \$16,000 | \$27,700 |
| 30 | 3 | \$20,200 | \$32,300 |
| 35 | 5 | \$24,700 | \$37,100 |
| 40 | 7.5 | \$29,300 | \$42,100 |
| 45 | 10 | \$34,100 | \$47,300 |
| 50 | 15 | \$39,100 | \$52,800 |
| Continuous Filtration Vibratory Centrifuge | | | |
| 48 | 30 | \$58,600 | \$91,900 |
| 50 | 40 | \$66,700 | \$100,900 |
| 52 | 50 | \$75,500 | \$113,000 |
| 54 | 60 | \$85,000 | \$124,000 |
| 56 | 75 | \$95,400 | \$135,800 |
| Reciprocating Conveyor, w/Continuous Filtering Centrifuge | | | |
| 15 | | \$112,900 | \$140,500 |
| 25 | | \$175,200 | \$213,200 |
| 35 | | \$246,100 | \$295,100 |
| 45 | | \$317,200 | \$376,200 |
| 50 | | \$352,900 | \$416,800 |

Filter

1st Quarter 1998 dollars

| Flow Rate (Gallons per minute) | Frame Capacity (Cubic feet) | Surface Area (Square feet) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|---|--|---|--|------------------------------------|
| Cartridge Filter | | | | |
| 30 | | | \$1,100 | \$5,200 |
| 100 | | | \$1,700 | \$6,800 |
| 300 | | | \$2,400 | \$8,300 |
| 600 | | | \$4,200 | \$10,300 |
| 900 | | | \$5,800 | \$13,500 |
| 1200 | | | \$7,300 | \$15,200 |
| Automatic Plate and Frame | | | | |
| | 10 | | \$100,200 | \$145,500 |
| | 20 | | \$114,200 | \$160,400 |
| | 30 | | \$123,300 | \$170,100 |
| | 40 | | \$130,200 | \$177,500 |
| | 50 | | \$135,900 | \$183,600 |
| Tubular Fabric Filter | | | | |
| 100 | | | \$5,500 | \$13,000 |
| 500 | | | \$15,700 | \$27,100 |
| 1000 | | | \$24,700 | \$39,900 |
| 1500 | | | \$32,200 | \$51,200 |
| 2000 | | | \$38,800 | \$59,500 |
| 2500 | | | \$44,900 | \$69,200 |
| 3000 | | | \$50,600 | \$76,400 |
| 3400 | | | \$54,900 | \$81,700 |
| Drum Filter | | | | |
| | | 100 | \$63,400 | \$104,200 |
| | | 250 | \$87,700 | \$134,400 |
| | | 500 | \$120,200 | \$175,400 |
| | | 750 | \$145,000 | \$205,200 |
| | | 1000 | \$168,900 | \$237,400 |
| | | 1500 | \$192,900 | \$275,700 |
| | | 2000 | \$208,300 | \$298,900 |

Agitators

1st Quarter 1998 dollars

| Driver Power (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--------------------------------------|--|--------------------------------|
| 2 | \$7,700 | \$9,500 |
| 10 | \$13,900 | \$15,900 |
| 25 | \$19,500 | \$21,600 |
| 50 | \$35,400 | \$37,700 |
| 75 | \$50,200 | \$52,700 |
| 100 | \$64,300 | \$67,000 |

Rotary Pump

1st Quarter 1998 dollars

| Capacity (Gallons/ minute) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|---|--|--------------------------------|
| 10 | \$1,500 | \$9,000 |
| 50 | \$2,100 | \$10,900 |
| 100 | \$2,400 | \$12,600 |
| 150 | \$3,000 | \$13,200 |
| 200 | \$3,400 | \$13,700 |
| 250 | \$4,100 | \$16,000 |
| 300 | \$4,400 | \$16,300 |
| 400 | \$5,300 | \$17,300 |
| 500 | \$7,000 | \$19,200 |
| 600 | \$8,700 | \$21,000 |
| 700 | \$10,700 | \$25,700 |
| 750 | \$11,600 | \$26,600 |

Inline Pump1st Quarter 1998 dollars

| Capacity (Gallons/ minute) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|---|--|--------------------------------|
| 10 | \$1,500 | \$9,000 |
| 50 | \$2,100 | \$10,900 |
| 100 | \$2,400 | \$12,600 |
| 150 | \$3,000 | \$13,200 |
| 200 | \$3,400 | \$13,700 |
| 250 | \$4,100 | \$16,000 |
| 300 | \$4,400 | \$16,300 |
| 400 | \$5,300 | \$17,300 |
| 500 | \$7,000 | \$19,200 |
| 600 | \$8,700 | \$21,000 |
| 700 | \$10,700 | \$25,700 |
| 750 | \$11,600 | \$26,600 |

Centrifugal Pump1st Quarter 1998 dollars

| Capacity (Gallons/ minute) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|---|--|--------------------------------|
| 100 | \$3,400 | \$22,800 |
| 200 | \$4,100 | \$23,800 |
| 300 | \$4,700 | \$27,700 |
| 400 | \$5,300 | \$28,500 |
| 500 | \$5,800 | \$29,000 |
| 1,000 | \$8,700 | \$37,500 |
| 2,000 | \$10,200 | \$44,800 |
| 3,000 | \$15,200 | \$58,100 |
| 4,000 | \$19,500 | \$72,300 |
| 5,000 | \$23,800 | \$77,100 |
| 6,000 | \$28,400 | \$93,400 |
| 7,000 | \$37,800 | \$103,000 |
| 8,000 | \$41,300 | \$119,700 |
| 9,000 | \$47,300 | \$126,200 |
| 10,000 | \$51,200 | \$144,800 |

Reciprocating Pump
1st Quarter 1998 dollars

| Capacity (Gallons/ minute) | Driver Power (Horse- power) | Duplex | | Triplex | |
|----------------------------------|--------------------------------------|--|---------------------------|--|---------------------------|
| | | Purchased Equipment Cost (\$) | Installed Cost (\$) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
| 25 | 2 | \$4,100 | \$10,600 | \$7,700 | \$15,500 |
| 50 | 5 | \$7,000 | \$14,600 | \$13,800 | \$22,700 |
| 100 | 7.5 | \$8,800 | \$17,800 | \$17,900 | \$28,200 |
| 200 | 15 | \$13,100 | \$22,500 | \$27,900 | \$38,600 |
| 300 | 25 | \$17,600 | \$28,800 | \$38,700 | \$51,200 |
| 400 | 30 | \$19,600 | \$31,000 | \$43,500 | \$56,200 |
| 500 | 40 | \$23,100 | \$34,700 | \$52,300 | \$65,300 |
| 600 | 50 | \$26,300 | \$38,100 | \$60,300 | \$73,400 |
| 700 | 60 | \$29,200 | \$43,700 | \$67,800 | \$83,700 |
| 800 | 60 | \$29,200 | \$43,700 | \$67,800 | \$83,800 |
| 900 | 75 | \$33,300 | \$48,100 | \$78,200 | \$94,500 |
| 1,000 | 75 | \$33,300 | \$48,200 | \$78,200 | \$94,500 |

Vacuum Pump
1st Quarter 1998 dollars

| Capacity (Gallons/ minute) | Stages | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|----------------------------------|--------|--|---------------------------|
| 30 | 1 | \$4,100 | \$18,600 |
| 75 | 1 | \$6,400 | \$21,100 |
| 150 | 1 | \$8,900 | \$24,000 |
| 200 | 1 | \$11,500 | \$26,900 |
| 300 | 1 | \$16,200 | \$32,300 |
| 400 | 1 | \$20,800 | \$37,100 |
| 500 | 1 | \$25,200 | \$41,800 |
| 600 | 1 | \$29,500 | \$46,300 |
| 700 | 1 | \$33,700 | \$50,800 |
| 30 | 2 | \$6,100 | \$20,600 |
| 75 | 2 | \$8,500 | \$23,200 |
| 150 | 2 | \$11,000 | \$26,100 |
| 200 | 2 | \$13,600 | \$29,000 |
| 300 | 2 | \$18,500 | \$34,600 |
| 400 | 2 | \$22,900 | \$39,200 |
| 500 | 2 | \$27,100 | \$43,700 |
| 600 | 2 | \$31,000 | \$47,800 |
| 700 | 2 | \$34,800 | \$51,900 |

Reciprocating Compressor

1st Quarter 1998 dollars

| Stages | Actual Capacity (Cubic feet/ minute) | Driver Power (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--------|--|------------------------------|-------------------------------------|------------------------|
| 1 | 250 | 40 | \$186,200 | \$245,500 |
| 1 | 500 | 75 | \$233,700 | \$300,300 |
| 1 | 1,000 | 125 | \$301,700 | \$380,400 |
| 1 | 5,000 | 600 | \$589,600 | \$717,500 |
| 1 | 10,000 | 1,250 | \$810,400 | \$970,700 |
| 1 | 25,000 | 3,000 | \$1,891,500 | \$2,139,000 |
| 1 | 50,000 | 5,500 | \$4,024,800 | \$4,469,700 |
| 1 | 60,000 | 7,000 | \$4,837,400 | \$5,354,000 |
| 3 | 250 | 100 | \$297,000 | \$358,800 |
| 3 | 500 | 150 | \$355,400 | \$422,200 |
| 3 | 1,000 | 300 | \$431,400 | \$509,700 |
| 3 | 5,000 | 1,500 | \$822,400 | \$932,300 |
| 3 | 10,000 | 3,000 | \$1,489,700 | \$1,646,100 |
| 3 | 25,000 | 7,000 | \$3,794,300 | \$4,135,200 |
| 3 | 35,000 | 10,000 | \$5,519,000 | \$6,038,600 |
| 3 | 250 | 800 | \$389,400 | \$467,200 |
| 3 | 500 | 1,500 | \$534,100 | \$627,400 |
| 3 | 1,000 | 3,000 | \$1,080,700 | \$1,211,500 |
| 3 | 5,000 | 15,000 | \$3,750,700 | \$4,211,800 |
| 3 | 7,000 | 22,500 | \$4,712,700 | \$5,317,700 |

Centrifugal Compressor

1st Quarter 1998 dollars

| Stages | Actual Capacity (Cubic feet/ minute) | Driver Power (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--------|--|------------------------------|-------------------------------------|------------------------|
| 4 | 500 | 60 | \$595,400 | \$702,700 |
| 4 | 1,000 | 125 | \$626,400 | \$749,300 |
| 4 | 5,000 | 600 | \$719,700 | \$907,100 |
| 4 | 10,000 | 1,250 | \$1,114,800 | \$1,339,000 |
| 4 | 50,000 | 6,000 | \$2,699,800 | \$3,247,700 |
| 4 | 100,000 | 12,000 | \$5,275,800 | \$6,142,000 |
| 4 | 150,000 | 17,000 | \$8,722,600 | \$9,735,100 |
| 4 | 200,000 | 25,000 | \$9,627,600 | \$10,980,400 |
| 9 | 500 | 125 | \$975,600 | \$1,066,700 |
| 9 | 1,000 | 250 | \$1,011,200 | \$1,118,500 |
| 9 | 5,000 | 1,250 | \$1,146,600 | \$1,286,000 |
| 9 | 10,000 | 2,500 | \$1,889,300 | \$2,060,500 |
| 8 | 50,000 | 12,000 | \$4,821,600 | \$5,356,700 |
| 8 | 100,000 | 25,000 | \$12,444,800 | \$13,267,000 |
| 7 | 150,000 | 37,500 | \$18,991,500 | \$19,966,000 |
| 7 | 200,000 | 50,000 | \$19,394,300 | \$20,624,400 |
| 9 | 500 | 1,750 | \$1,446,400 | \$1,548,200 |
| 9 | 1,000 | 3,500 | \$1,560,500 | \$1,680,300 |
| 9 | 5,000 | 16,000 | \$2,258,600 | \$2,527,000 |
| 9 | 10,000 | 32,500 | \$4,053,700 | \$4,467,800 |
| 9 | 15,000 | 50,000 | \$5,171,000 | \$5,718,400 |

Centrifugal Fan

1st Quarter 1998 dollars

| Actual Capacity (Gallons/ minute) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|---|-------------------------------------|------------------------|
| 700 | \$1,100 | \$7,000 |
| 1,500 | \$1,100 | \$7,400 |
| 5,000 | \$1,800 | \$9,800 |
| 10,000 | \$2,500 | \$13,100 |
| 25,000 | \$6,700 | \$27,900 |
| 50,000 | \$13,300 | \$49,900 |
| 75,000 | \$19,900 | \$64,900 |
| 100,000 | \$31,400 | \$93,400 |
| 150,000 | \$44,600 | \$126,500 |

Rotary Blower1st Quarter 1998 dollars

| Actual Capacity (Gallons/ minute) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--|--|--------------------------------|
| 100 | \$4,800 | \$11,500 |
| 500 | \$10,400 | \$19,100 |
| 1,000 | \$15,000 | \$24,900 |
| 2,000 | \$22,000 | \$34,800 |
| 3,000 | \$28,100 | \$44,400 |
| 4,000 | \$36,700 | \$54,600 |

Gas Turbine1st Quarter 1998 dollars

| Power Output (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--------------------------------------|--|--------------------------------|
| 1,000 | \$476,200 | \$565,200 |
| 5,000 | \$1,254,100 | \$1,376,400 |
| 10,000 | \$1,903,000 | \$2,051,300 |
| 50,000 | \$9,639,300 | \$9,975,400 |
| 100,000 | \$16,148,100 | \$16,738,600 |
| 150,000 | \$21,837,300 | \$22,659,400 |
| 200,000 | \$27,052,000 | \$28,056,000 |
| 250,000 | \$31,940,100 | \$33,192,400 |
| 300,000 | \$36,583,000 | \$37,998,000 |
| 350,000 | \$41,031,000 | \$42,609,000 |
| 370,000 | \$42,764,000 | \$44,407,000 |

Steam Turbine1st Quarter 1998 dollars

| Power Output (Horsepower) | Purchased Equipment Cost (\$) | Installed Cost (\$) |
|--------------------------------------|--|--------------------------------|
| 10 | \$19,100 | \$36,000 |
| 50 | \$25,200 | \$46,500 |
| 100 | \$28,500 | \$53,600 |
| 500 | \$37,700 | \$108,800 |
| 950 | \$42,100 | \$126,700 |
| 1,000 | \$85,000 | \$169,800 |
| 2,500 | \$269,000 | \$364,400 |
| 5,000 | \$575,000 | \$688,000 |
| 7,500 | \$781,400 | \$907,900 |
| 10,000 | \$971,400 | \$1,106,600 |
| 15,000 | \$1,320,100 | \$1,477,100 |
| 20,000 | \$1,641,100 | \$1,825,200 |
| 30,000 | \$2,230,200 | \$2,447,300 |