APPENDIX 1

EQUIPMENT COST ESTIMATES

The following section provides very rough cost estimates for a wide variety of process equipment. It must be remembered in using these charts that there is no such thing as an exact, definite, fixed price for any piece of equipment of a given size or capacity. As with buying merchandise, clothing or a car there are many styles, quality differences, optional features and designs to meet specific needs or services. Presumably charts could be made for each of these variations, but the number would be large and confusing, and for many preliminary estimates the engineer would not know exactly what he wanted at that stage of the design, so only average, representative equipment should be more useful. Again, a range of prices could be shown, but usually a single line is more practical, keeping in mind that the price could quite normally vary considerably depending upon the exact design requirements and the company policy on quality, maintenance, and so on.

With these generalities in mind, the following charts have been taken from a number of sources. Most are from cost estimating articles or books, although some are from recent vendor quotations. In case only a single source was available, that reference has been noted. However, often many sources were available and a somewhat biased consensus of opinion curve was selected. In this case the sources were not noted except for inclusion in the reference list at the end of the appendix. In case different variables were used as the sizing parameter, the most logical one in the author's opinion was selected.

All costs were factored to an early 1987 basis, or a chemical engineering index number of 320. When equations were available for the cost relationship they were listed beneath the charts, and when straight line functions existed for the costs on log–log paper a sizing exponent was given:

$$\text{cost size 2} = \text{cost size 1}\left(\frac{\text{size 2}}{\text{size 1}}\right)^{\text{size exponent}}$$

In a number of references various authors have estimated the fraction of the purchased equipment cost that it takes to install the equipment. This generally included freight and shipping costs, foundations, mounting, and simple electric and piping connections, such as switch gear, starters, flange connections, and so on. Unfortunately these numbers often varied widely, so the range and average are both listed when available:

installed cost = purchase price × installation factor

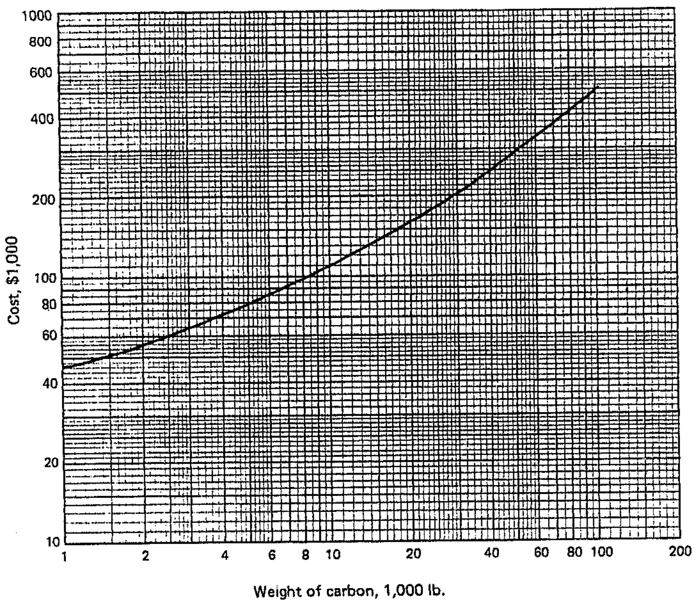
A similar number that also includes all of the adjacent minor equipment and connections is sometimes listed in the literature (principally by Guthrie 1975 and Ulrich 1984) covering the cost of purchase and installation of the major equipment as well as all of the supporting equipment around each major unit. This is called the module factor, and when available is also listed under the charts as the range given by different authors and the average value.

cost of the installed module = purchase price × module factor

As a final item under the equipment cost graphs, often a simple factor can be used to estimate the cost of some other material, pressure, size, or other variable for the equipment, than is shown on the graph. For instance, the cost of a stainless steel agitated tank is 1.7 times the cost of a mild steel tank (which is shown on the chart). These factors have also been listed when available, and again, sometimes as a consensus of different authors' estimates.

Adsorbers, Activated Carbon

Mild steel construction, including instruments and controls



Equations:

Cost = 15,200 + 1, $100W_c^{0.481}$ for W_c >250, <10,000 lb.

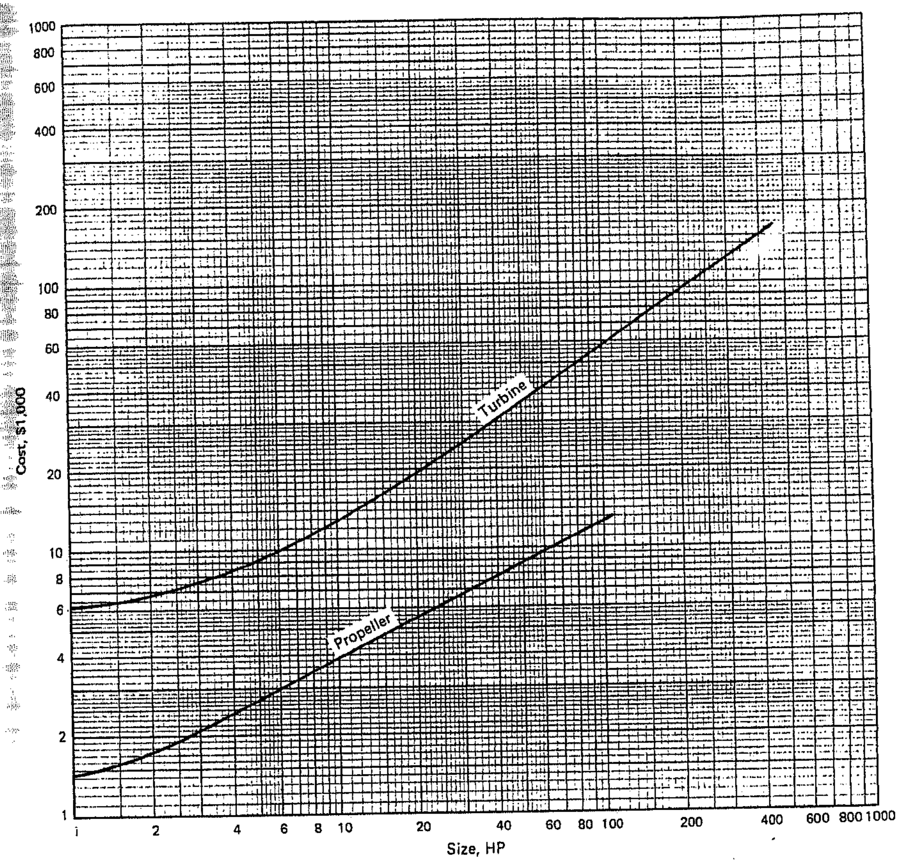
Cost = 76,200 + $0.422W_c^{1.2}$ for W_c >10,000, <200,000 lb.

W_c = weight of activated carbon, lb.

Agitators

Dual turbine blades; mild steel; 30-45 rpm, motor, gear reduction, shaft

Propeller; mild steel, single blade



Size exponent:

Turbine:	>30 HP	0.68
	4-30 HP	0.56
	<4 HP	0.23
Propeller:	3-100 HP	0.51
	1-3 HP	0.42

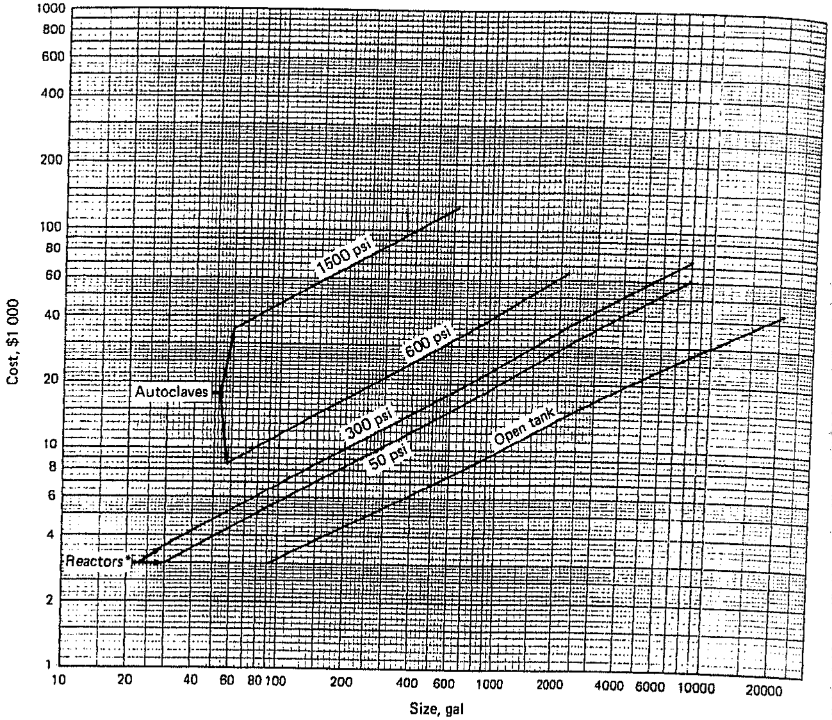
Installation factor:

	Range	Average
Turbine	1.20-40	1.32
Propeller	1.12-32	1.22

Module factor 2.0

Factors for:	Range	Average
Turbine:		
Single blade	0.75-0.85	0.82
56-100 rpm	0.57-0.70	0.66
125-230 rpm	0.37-0.51	0.47
316 stainless	1.23-1.87	1.47
Propeller:		
Stainless steel		1.19
With seal (for closed tank)		1.32

Agitated Tanks*
Jacketed, agitated, mild steel



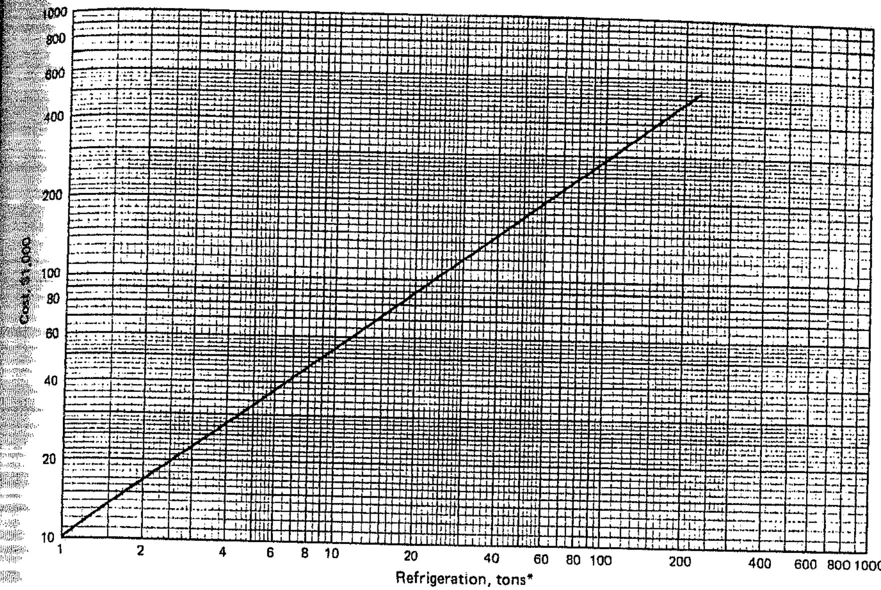
Size exponent 0.53
Module factor 2.5

Installation factor:

	Range	Avg.
Open tank	1.41 - 66	1.58
Low pressure	1.30 - 57	1.44
Autoclave	1.50 - 70	1.60

Material factors:
Stainless steel
1.2 - 2.2, avg. = 1.7
Glass lined
1.2 - 2.0, avg. = 1.6
*See Reactors

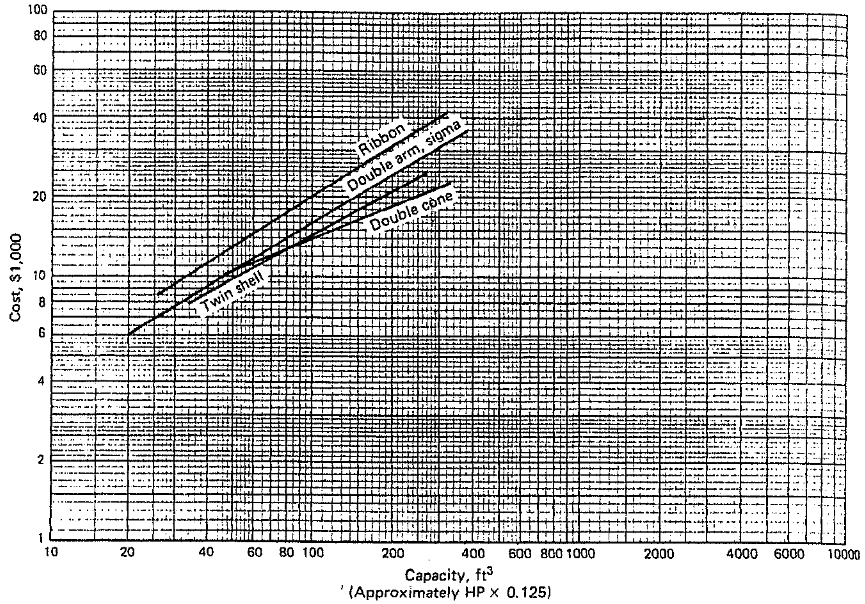
Air Conditioning
Compressor, motor, controls, condenser, refrigerant



Size exponent 0.73
Installation, Module factor
1.38-53 avg. 1.46

*One ton = 12,000 Btu

Blenders
Mild steel construction



Size exponents:
Ribbon, double arm, sigma, twin shell 0.60
Double cone 0.42

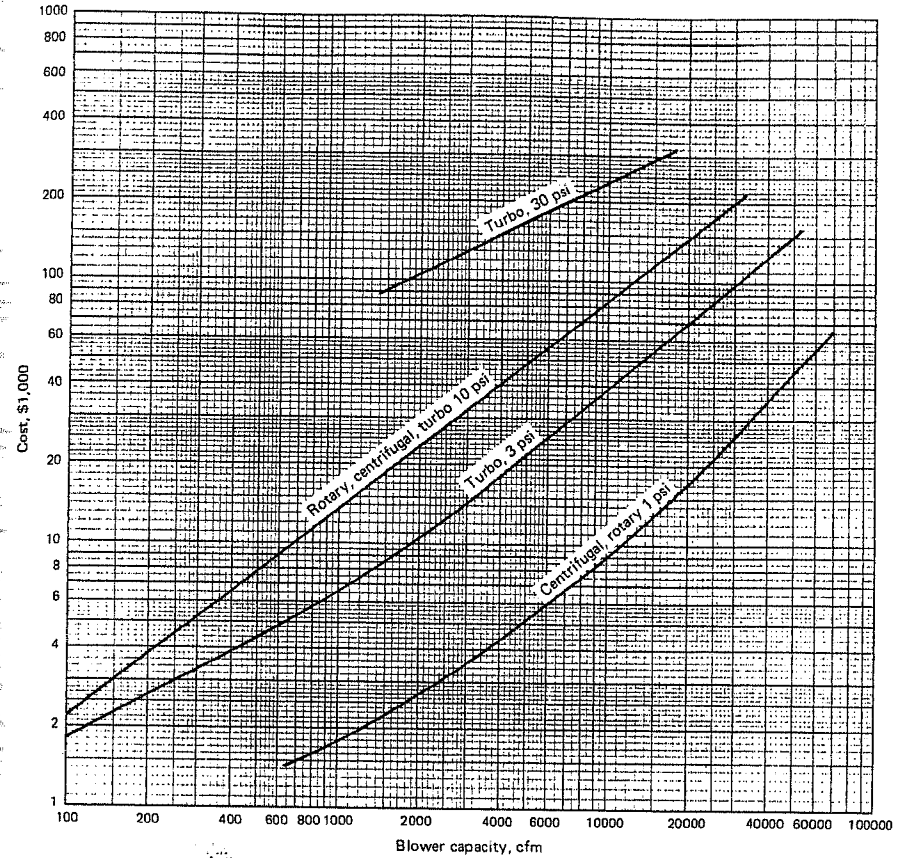
Material factor:
304 stainless steel 1.6

Installation factor 1.30

Module factor:

Ribbon	2.0
Sigma	2.8
Double arm, cone, twin shell	2.2

Blowers
30-in. water (~1 psi) to 30 psi; cast iron, with motor



Size exponent:

30 psi	0.52
10 psi	0.79
<3 psi	variable

Installation factor:

Range:	1.35-56
Average:	1.42

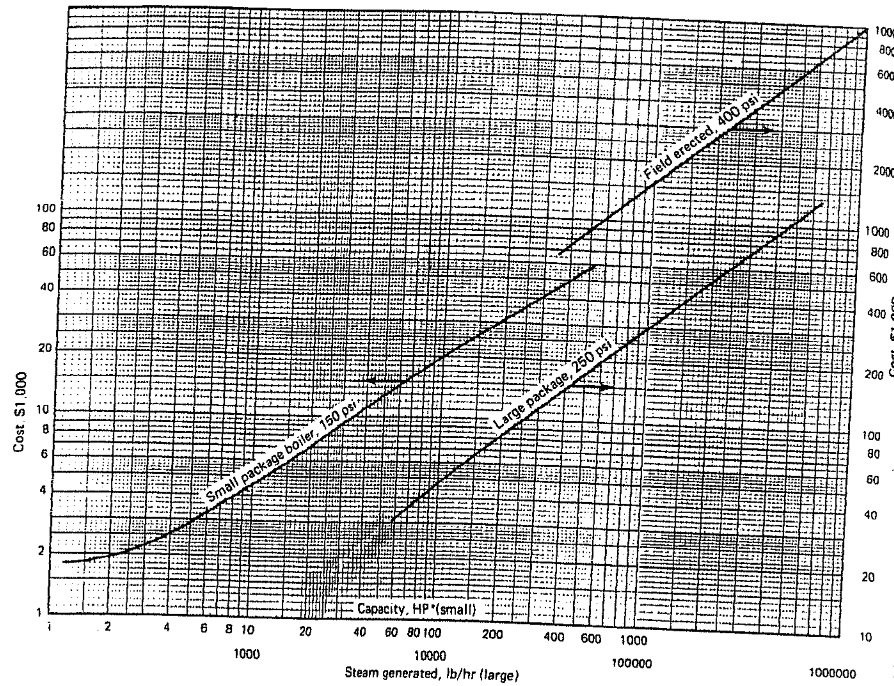
Module factor:

Rotary	2.2
Centrifugal	2.5

Material factors:

Fiberglass	2.5 to 4; avg. ~2.6
Stainless steel	2.6

Boilers



Size exponents:
Package boilers
5 - 1,000 HP 0.65
6 - 600 · 10^3 lb/hr 0.77
Field erected 0.82

*One HP = 33,5000 Btu

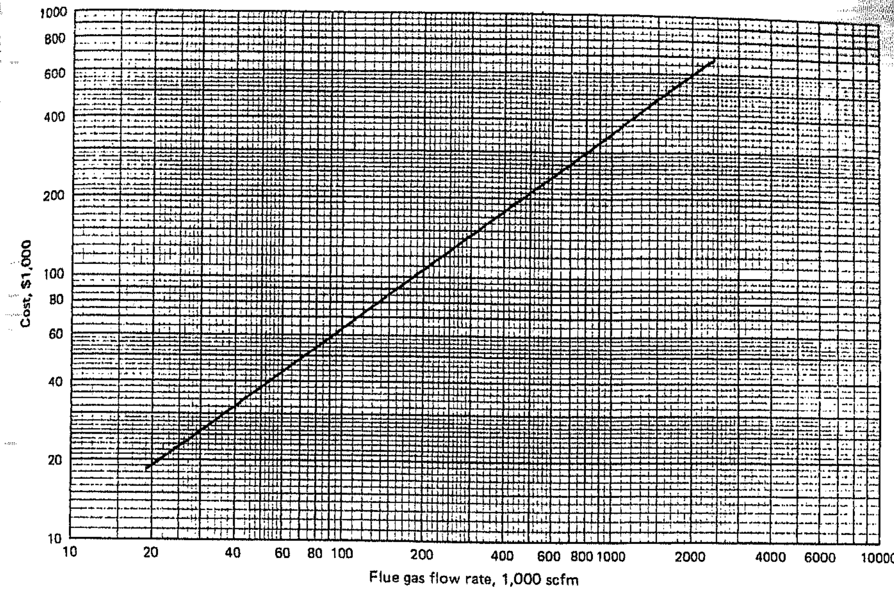
Installation factor:
1.21 - 82 avg. 1.53

Module factor:
Package 1.8
Field erected 1.8 - 2.0 avg. 1.9

Pressure factor:
Large package
400 psi 1.31
500 psi 1.74
Field erected
1000 psi 1.35
3000 psi 1.58

Coal fired
Large package 1.61
Field erected 1.36

Boilers, Waste Heat



Size exponent 0.75

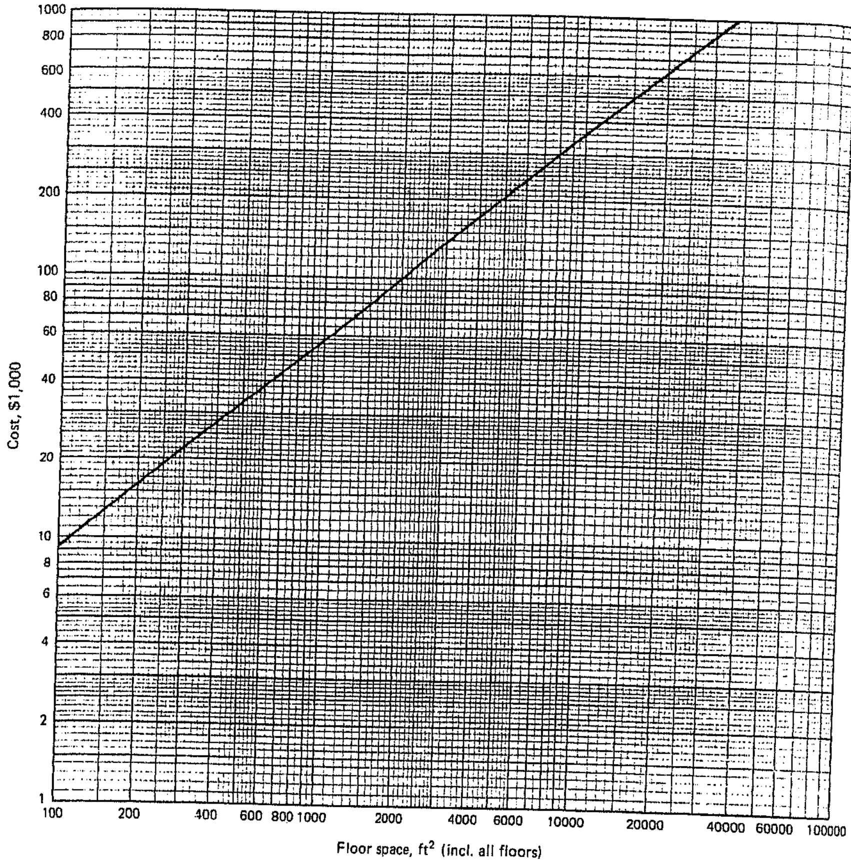
Installation factor:
1.40-82 avg. 1.67

Module factor 1.81

Factors:
High-temperature operation 1.2
Finned tubes 1.5
Alloy-clad tubes 3.0
Mechanical ash removal 1.8
Radiation section 2.0

Buildings

Office type with air conditioning, restrooms, plaster or equivalent walls, insulation, modest architectural features



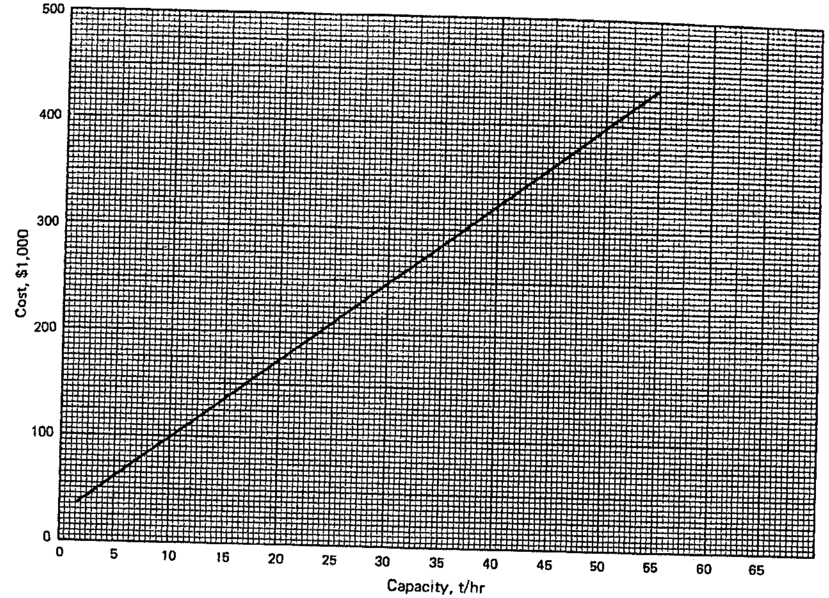
Size exponent 0.8

Factors:

Warehouse	0.25
Laboratory	1.5
Manufacturing bldg.	0.5

Centrifuges

Solid-bowl, screen-bowl, pusher types, 316 stainless steel



Installation factor:

Range 1.20–2.02 avg. 1.54

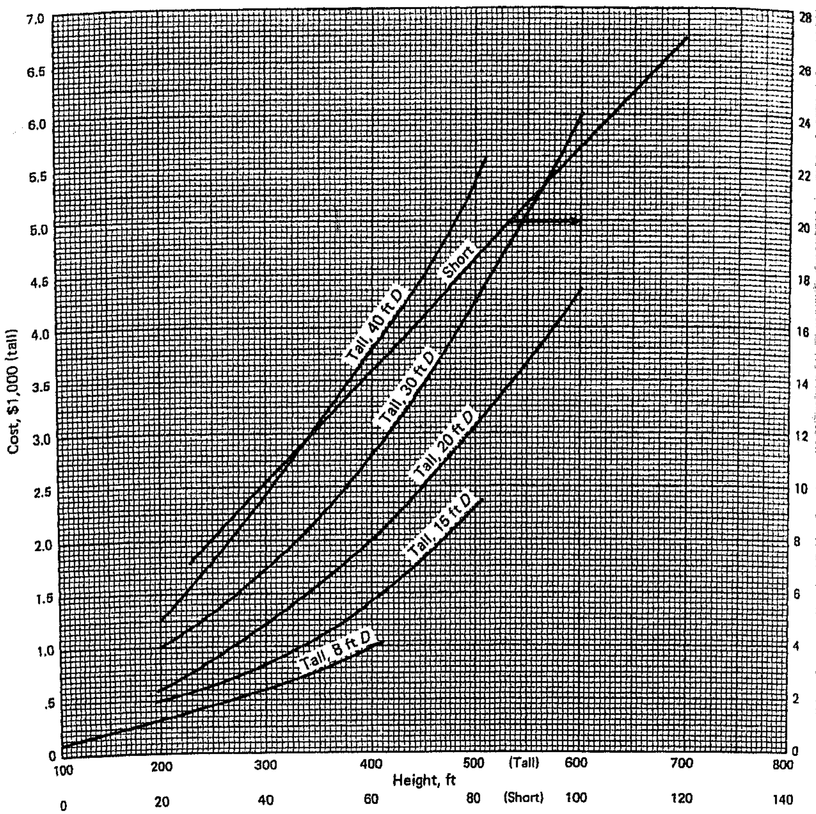
Module factor: 2.0

Material factors:

Carbon steel	0.68
Monel	1.35
Nickel	1.7
Hastalloy C	2.6

Chimneys, Stacks

Carbon steel, lined, insulated, with foundations (tall); No lining (short)



Size exponent, Tall 1.63

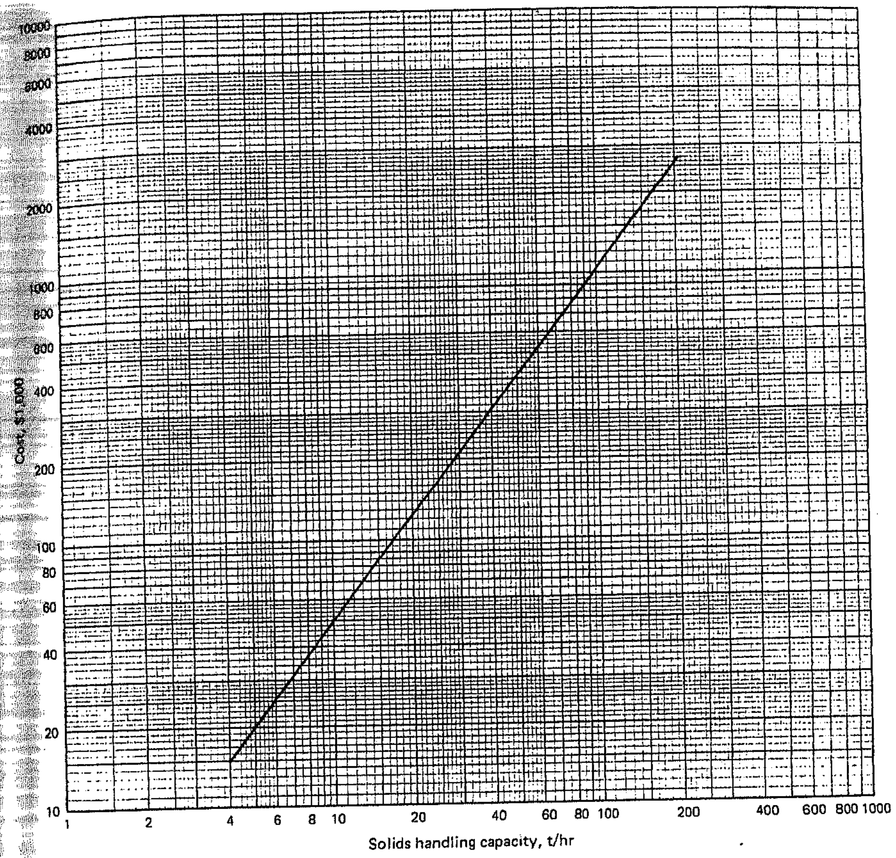
Installation factor: 1.20-28 avg. 1.24

Factors for:
Brick lined 2.3
Concrete 3.8
Diameter (short) $\left(\frac{D}{54 \text{ in.}}\right)^{1.55}$

Material factor, Short
Acid resistant, Fiberglass 1.3

Classifier, Rake or Spiral

Mild steel construction

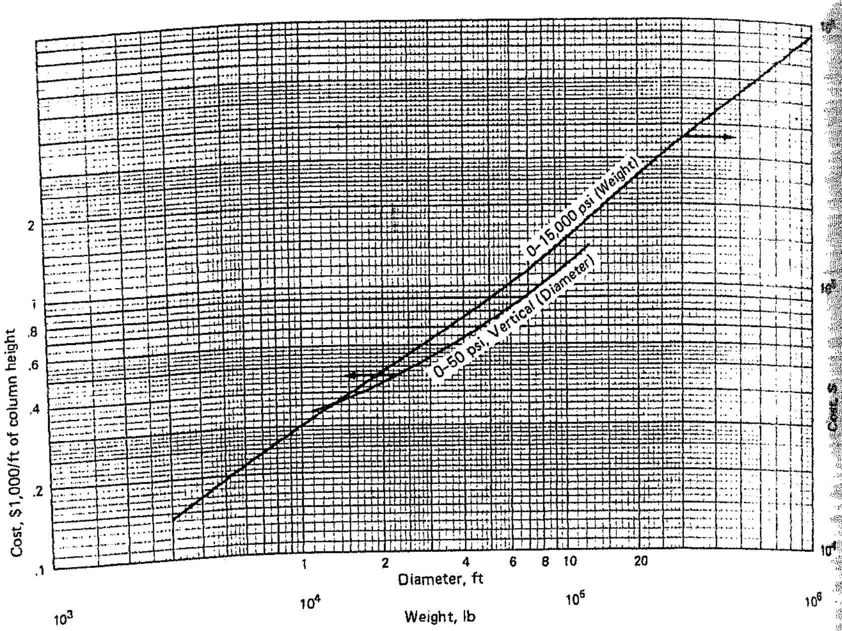


Size exponent 1.32

Installation factor
1.63-2.61 avg. 2.12

Module factor 2.3

Columns, Distillation, Absorption Towers, etc.
Mild steel construction, 0-50 psi, vertical



Size exponent
10^5-10^6 lb 0.78

Installation cost:
1.29-2.03 avg. 1.72

Module factor

Vertical	4.16
Horizontal	3.05

Material factors

Carbon steel	1.0
Stainless 304	1.7
Stainless 316	2.1
Monel 400	3.6
Titanium	7.7
Carpenter 20 CB-3	3.2
Nickel 200	5.4
Inconel 600	3.6
Incolcy 825	3.7

Other factors

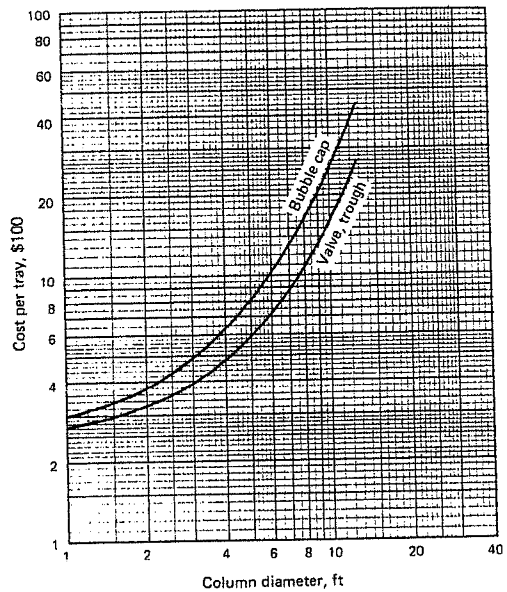
Horizontal vessel 0.6

Pressure $\frac{P}{50}^{0.44}$ or see chart

Pressure factors (vertical)

psi		psi	
50	1.00	800	3.80
100	1.25	900	4.00
200	1.55	1,000	4.20
300	2.00	1,500	5.40
400	2.40	2,000	6.50
500	2.80	3,000	8.75
600	3.00	4,000	11.25
700	3.25	5,000	13.75

Column Trays
Mild steel



Installation factor 1.20

Number factor:

25	1
20	1.05
15	1.25
10	1.50
5	2.30
1	3.0

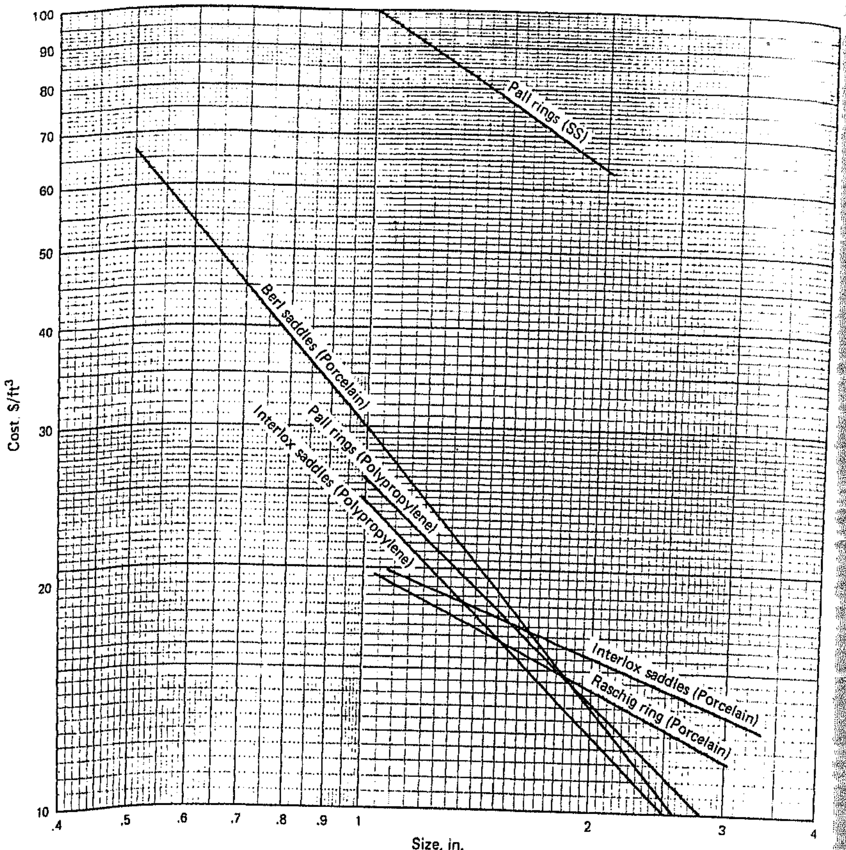
Tray type factor:

Turbo grid (stamped)	0.8
Grid, plate, seive	1.0
Trough, valve	1.2

Material factor:

Brass	1.2
304 stainless	1.5
316 stainless	1.9
347 stainless	2.1
Inconel	3.3
Monel	7.7

Column Packing

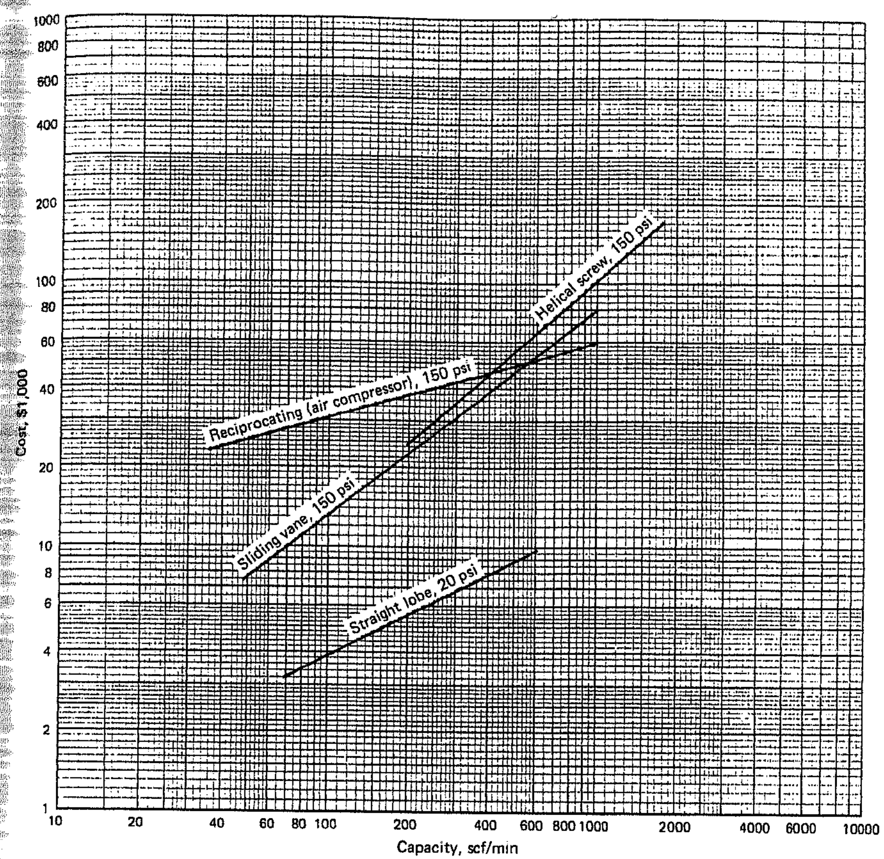


Material Factors; size exponents

Material	Size exponent	Ratio for other material	
Berl saddles		1.24	Stoneware
Porcelain	−1.16		
Pall ring SS	−0.64	0.30	Carbon steel
Polypropylene	−0.95		

Material	Size exponent	Ratio for other material	
Interlox saddles			
Porcelain	−0.4	0.94	Stoneware
Polypropylene	−0.95		
Raschig rings			
Porcelain	−0.5	6.11	Stainless steel
		2.35	Carbon
		1.58	Mild steel
		0.78	Stoneware

Compressors, Medium-Low Pressure



Size exponents:

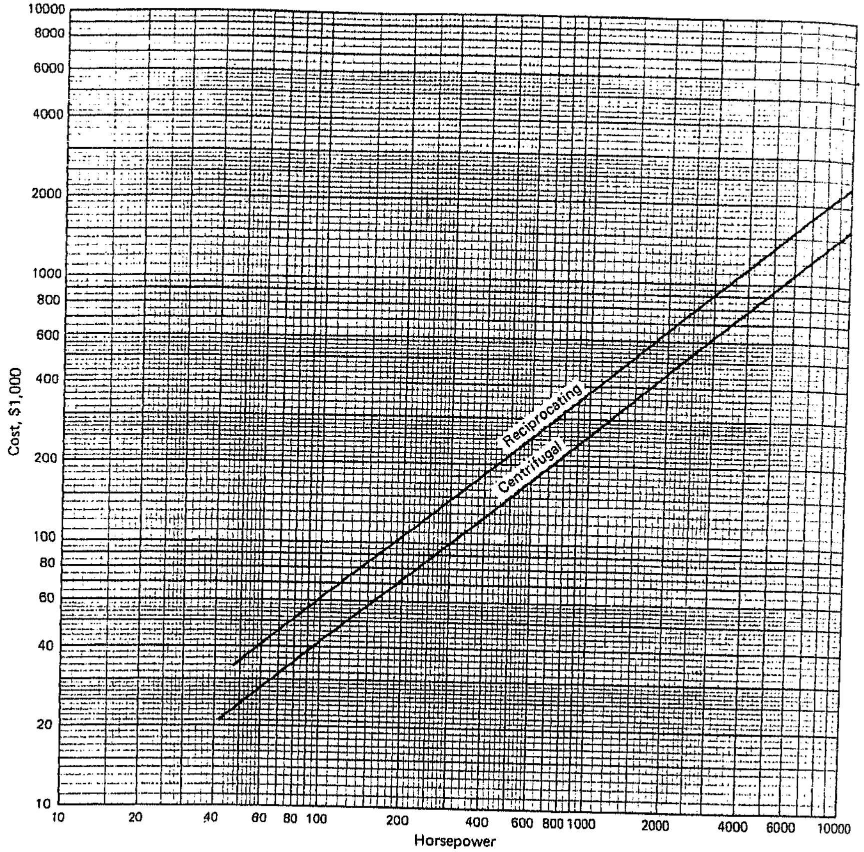
Straight lobe	0.51
Sliding vane	0.79
Helical screw	0.87
Reciprocating (air)	0.34

Installation factor:
1.30–87; avg. 1.49

Module factor:
2.2–3.1; avg. 2.6

Factors:
Straight lobe:
Pressure $\left(\frac{P}{20}\right)^{0.16}$

Compressors, High-Capacity and/or Pressure
1,000 psi; electric motor drive, gear reducer, steel



Size exponent 0.80

Equation:
(Isothermal compression)
$HP = 0.0044 P_1 Q_1 \ln P_2/P_1$
P_1 = inlet pressure, psi
P_2 = outlet pressure, psi
Q_1 = inlet flow rate, cfm

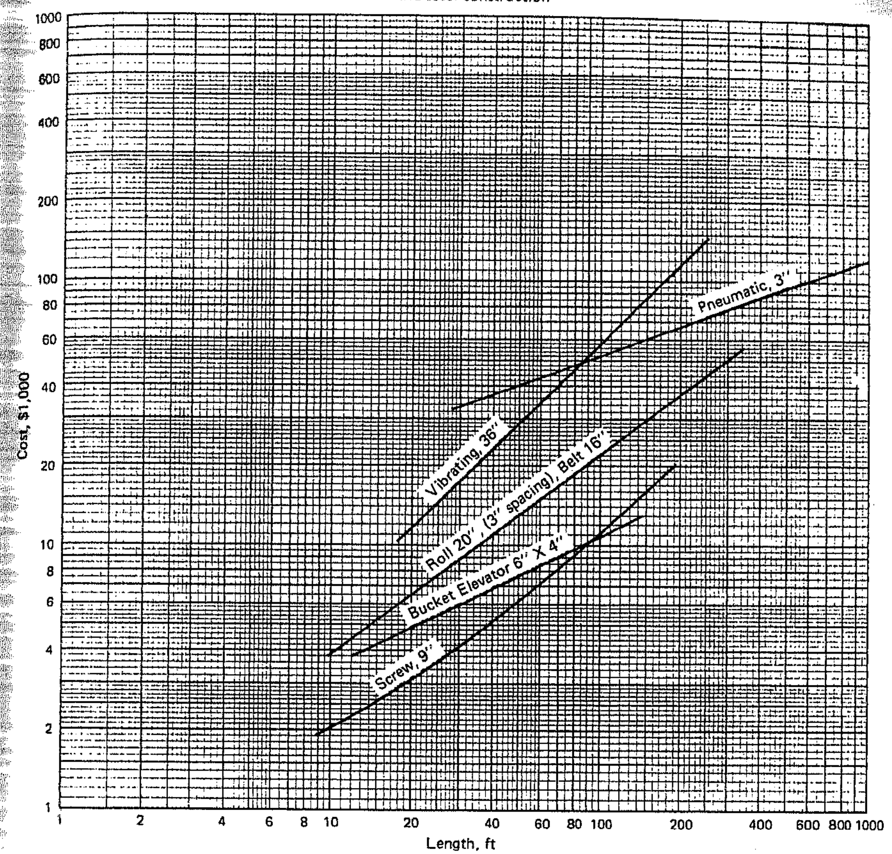
Installation factor:
1.30–87; avg. 1.49

Module factor:
2.15–3.1; avg. 2.6

Factors:

Turbine drive	1.13
Gas engine	1.41
Pressure $\left(\frac{P}{1000}\right)^{0.18}$	
Stainless steel	2.5
Nickle alloy	5.0

Conveyors
Mild steel construction



Size exponent:

Screw conveyor	0.78
Belt conveyor	0.76
Bucket elevator, roll	0.5
Pneumatic conveyor	0.37
Vibrating	1.0

Installation factor:
Range 1.40–2.15 avg. 1.72

Module factors:

Screw, pneumatic, roll	2.2
Belt, bucket, vibrating	2.4

Size factors:

Screw conveyor $\left(\frac{\text{diameter}}{9\text{ in.}}\right)^{1.2}$

Belt conveyor $\left(\frac{\text{width}}{16\text{ in.}}\right)^{0.6}$

Bucket elevator $\left(\frac{\text{bucket wd. X ht.}}{6 \times 4 = 24\text{ in.}^2}\right)^{0.37}$

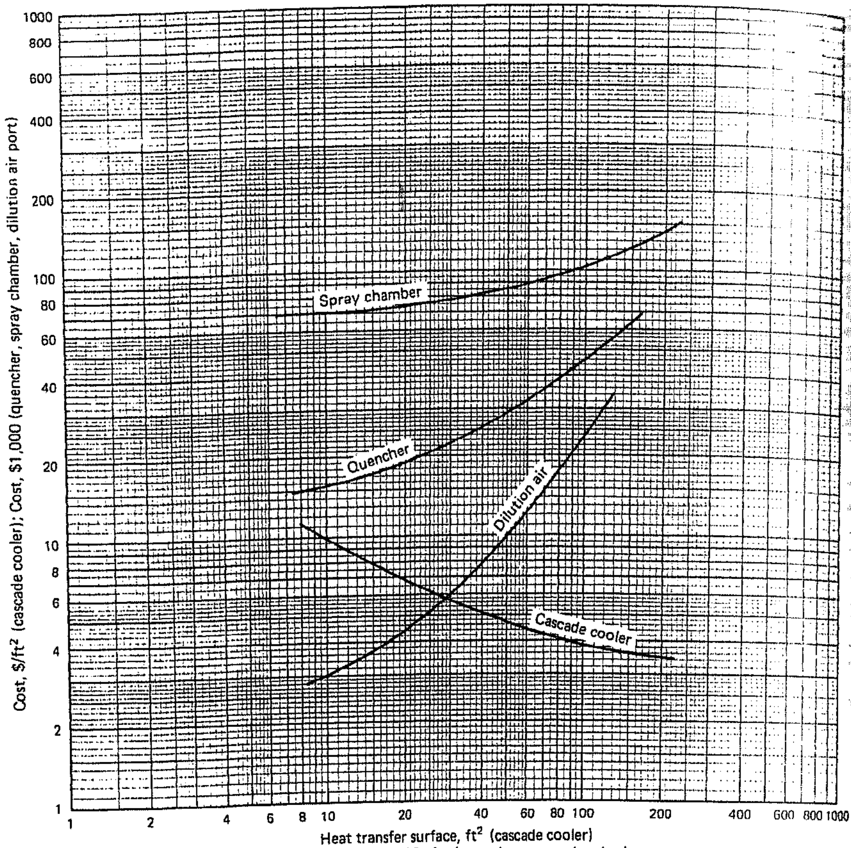
Pneumatic conveyor $\left(\frac{\text{diameter}}{3\text{ in.}}\right)^{0.55}$

Roll $\left(\frac{\text{width}}{20\text{ in.}}\right)^{0.55}$; 4 in. spacing X 0.84

Vibrating $\left(\frac{\text{width}}{36\text{ in.}}\right)^{0.57}$

Coolers, Quenchers

Mild steel construction; Cascade cooler, 2 in. diameter pipe



Installation factor:

1.40–1.85; avg. 1.62

Module Factor:

Spray chamber, quencher 2.7

Equations:

Spray chamber: \$(358 X M scf + 65,000)

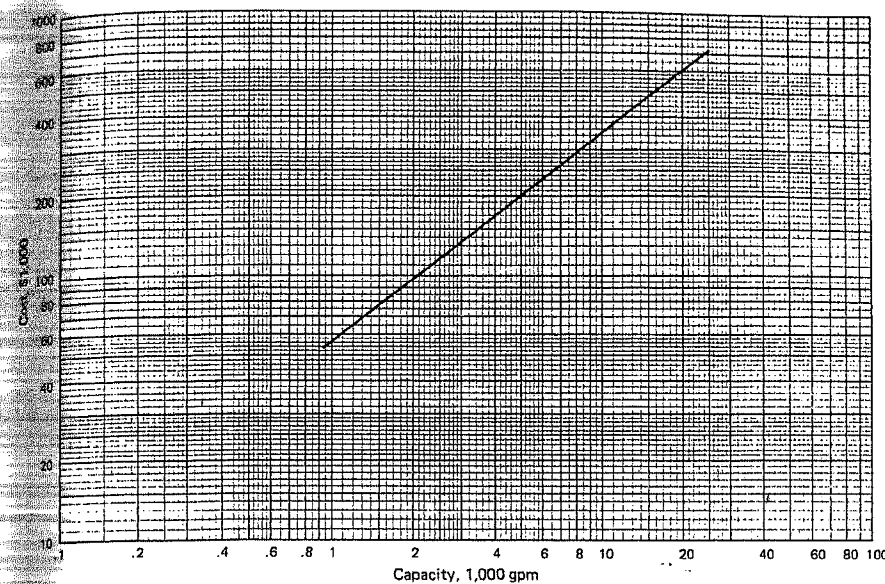
Quencher \$(335 X M scf + 12,200)

Factors:

Cascade cooler $\left(\frac{\text{pipe diameter}}{2\text{ in.}}\right)^{0.6}$

Cooling Tower

15°F range, 10°F approach, 82°F wet bulb



Size exponent 0.79

Installation factor 1.20

Module factor 1.70

Factors;

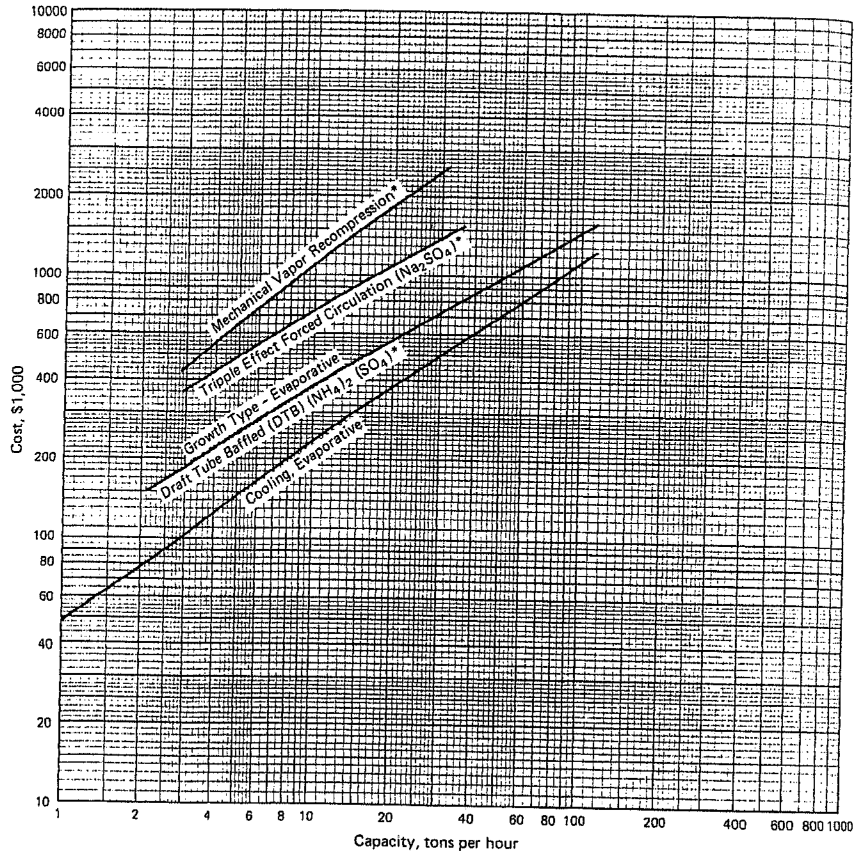
Range: $\left(\frac{T°F}{15}\right)^{0.57}$

Wet bulb temperature

°F	Factor
68	0.65
70	0.68
72	0.72
74	0.77
76	0.82
78	0.87
80	0.93
82	1.00

Approach, Δ°F	Factor
6	1.60
8	1.20
10	1.00
12	0.85
16	0.65
20	0.50
24	0.40

Crystallizers
Mild steel construction



Size exponent:

Cooling, evaporative	0.68
Growth, forced circulation, DTB	0.63
Vapor recompression	0.75

Installation factor:
1.30-2.03, avg. 1.80

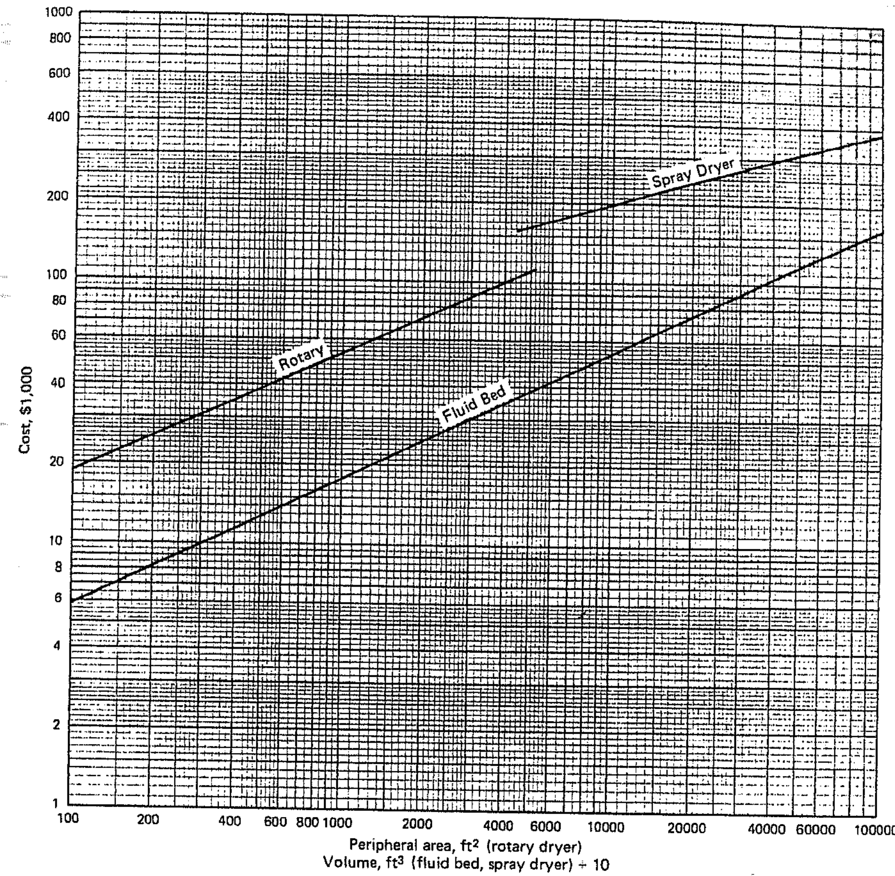
Module factor:
2.4-2.9, avg. 2.6

Material factors:

Stainless steel	2.1
Copper alloy	1.3
Nickel alloy	2.6
Titanium	6.0

*Courtesy of Swenson.

Dryers
Mild steel construction



Size exponents:

Rotary dryer	0.45
Fluid bed	0.48
Spray dryer	0.29

Installation factor:
1.25-96; avg. 1.64

Module factor:

Rotary	2.3
Fluid, spray	2.7

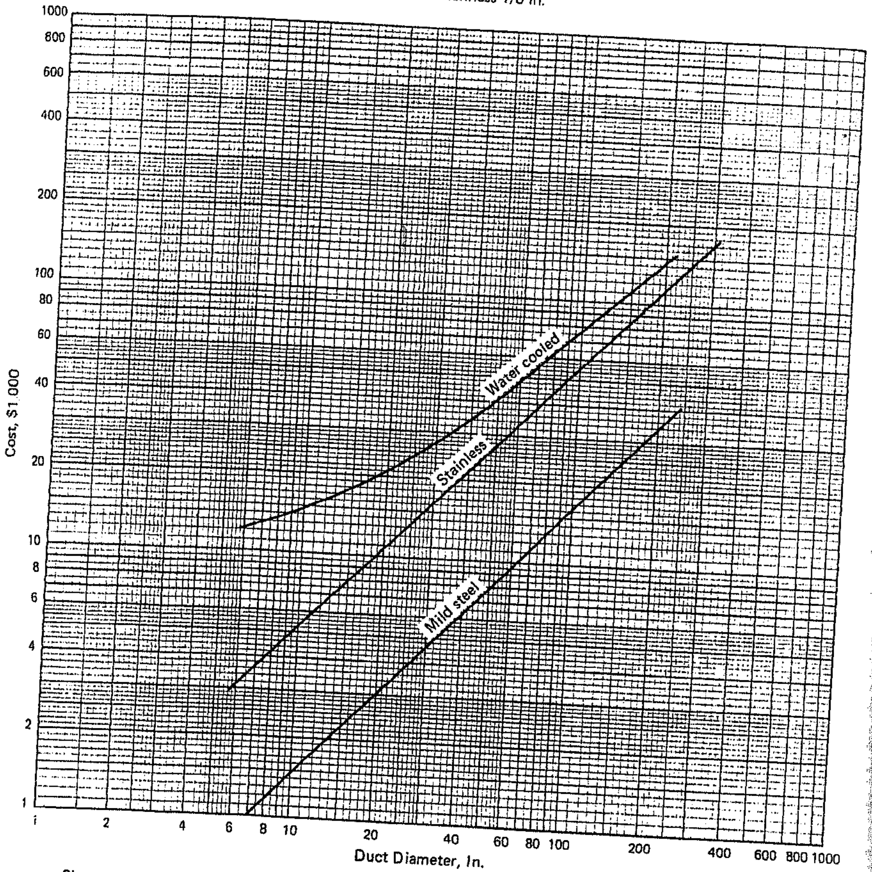
Factors:
Rotary to:

Roto-Louvre	1.25
Vacuum shelf (shelf area)	0.35

Materials:

Nickle alloy	3.7
Brick-lined, stainless steel	2.2

Ducts
Wall thickness 1/8 in.



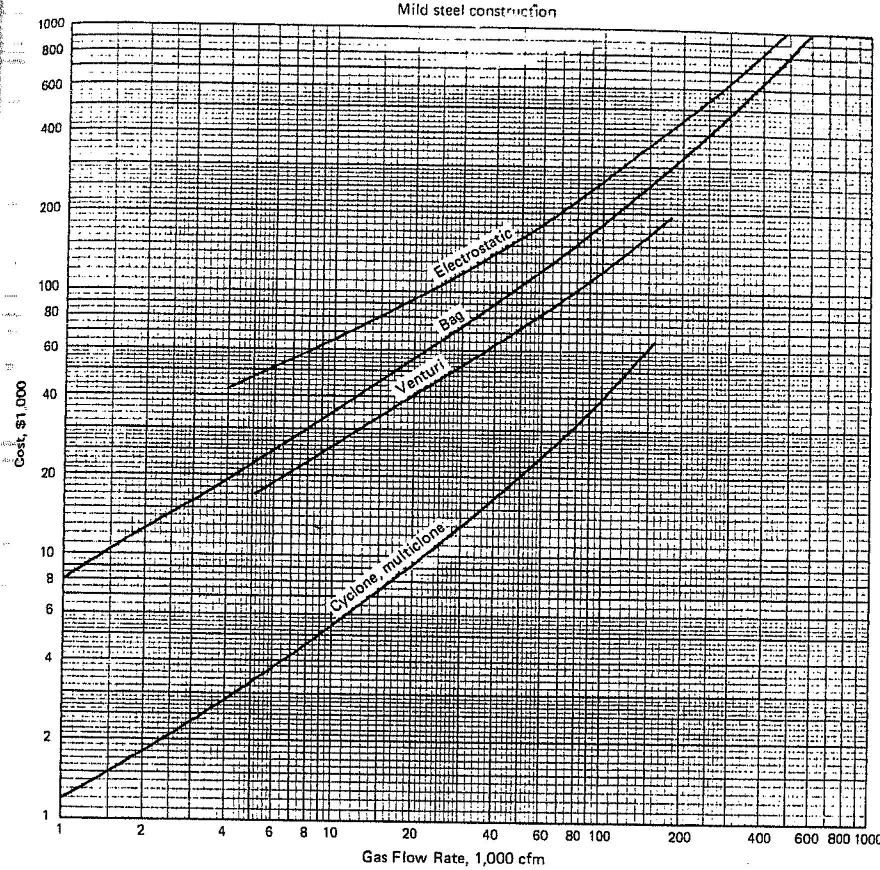
Size exponent: 1.08
Installation factor: 1.45

Equations: $/ft

Mild steel	(−2.22 + 1.66*D*)
Stainless	(−6.43 + 5.84*D*)
Water cooled	(79 + 6.78*D*)

Factors:
Mild steel:
(wall thickness/1/8 in.)$^{0.68}$
Stainless:
(wall thickness/1/8 in.)$^{1.0}$

Dust Collectors
Mild steel construction



Installation factor:
1.76–2.00; avg. 1.90

Module factors:

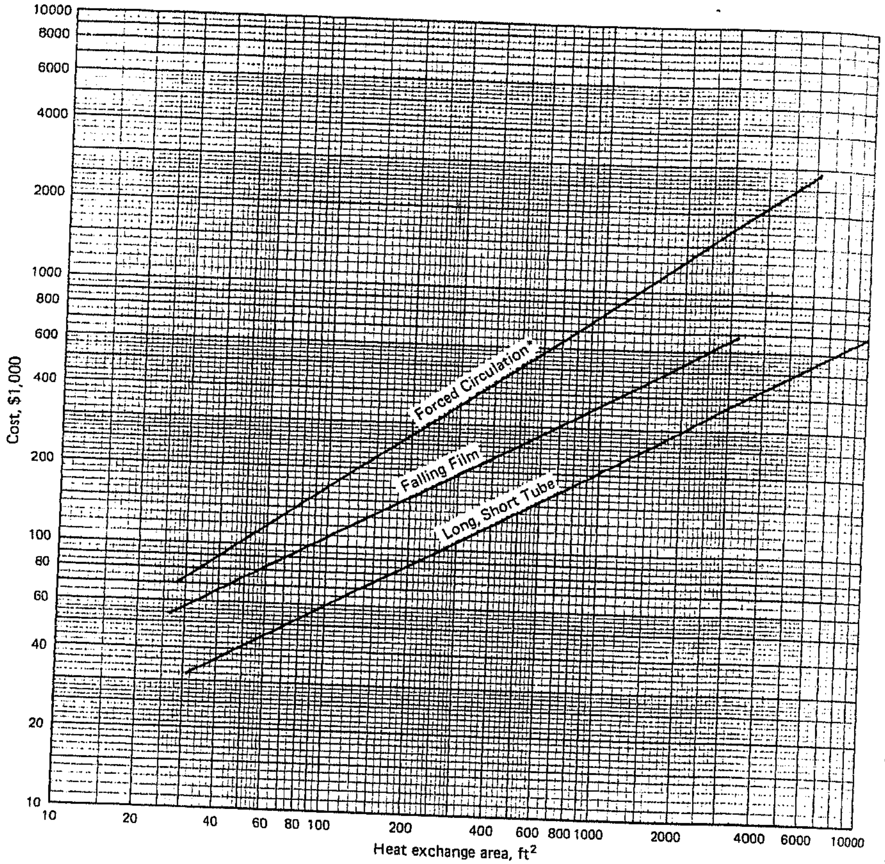
Electrostatic precipitators	2.3
Bag filters	2.2
Venturi scrubber	2.5
Cyclone, multiclone	3.0

Material factors for venturi, cyclone scrubbers:

High temperature with membrane, brick lining	1.6
304 Stainless	1.8
316L Stainless	2.1
316L Stainless, clad	1.9
Monel	3.0
Monel clad	2.7
Titanium	3.2

Evaporators*

Single effect; stainless steel



Size exponents:

Forced circulation	0.7
Falling film, long, short tube	0.53

Installation factor:

1.5–2.50; avg. 2.09

Module factor:

Forced circulation	2.9
Falling Film	2.3

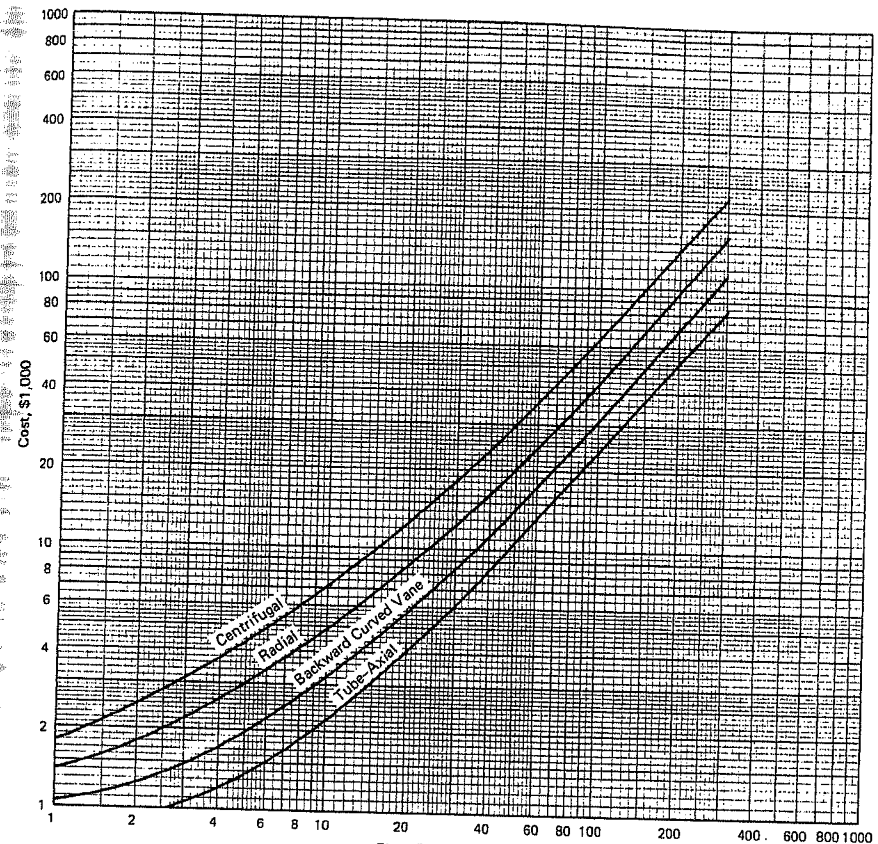
Material factors:

Mild steel	0.44
Copper alloy	0.57
Nickle alloy	1.22
Titanium	2.93

*Also, see Cyrstallizers

Fans

Mild steel; motor, starter; 3½ in. $H_2O \Delta P$



Installation factor:

Range: 1.30–2.05; avg. 1.61

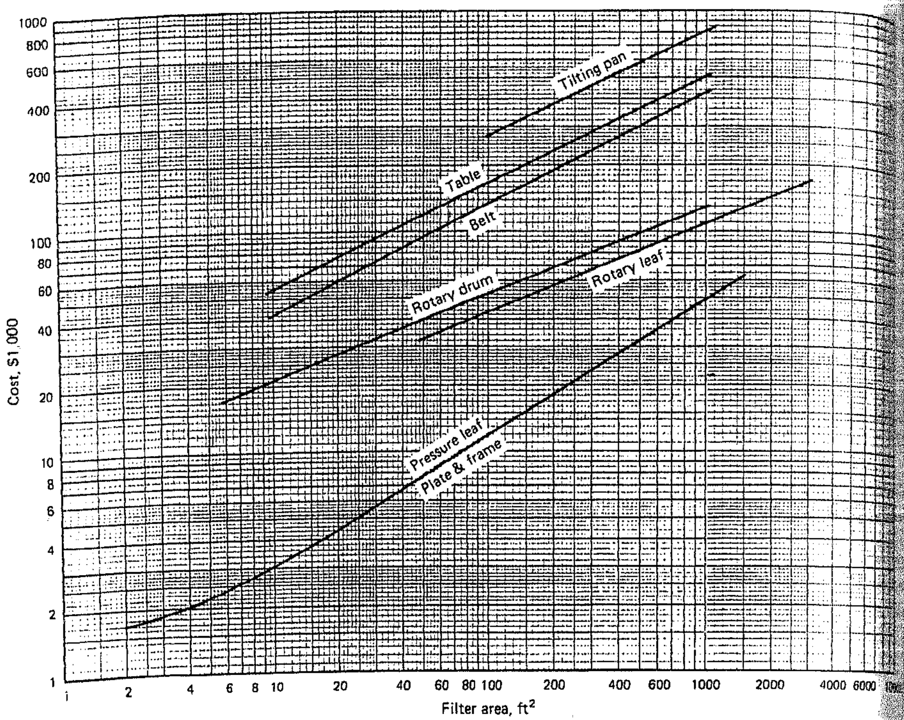
Module factor: 2.2

Factors:

Pressure: $\left(\frac{\Delta P}{3.5}\right)^{0.3}$

Fiberglass:	1.8
Stainless steel:	2.5

Filters
Stainless steel



Size exponents:

Rotary vacuum drum, leaf	0.39
Vacuum table, tilting pan, belt	0.5
Pressure leaf, plate & frame	0.61

Installation factor:
1.19 - 2.21; avg. 1.69

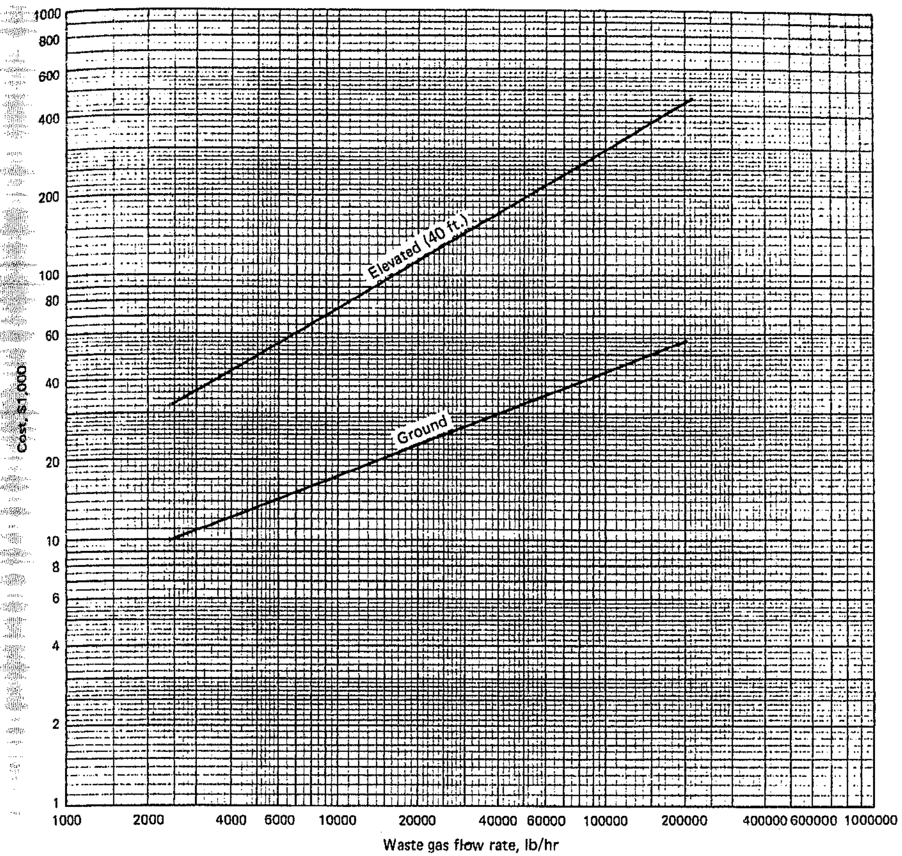
Module factor:
Rotary table, belt, tilting pan
1.4 - 2.8; avg. 2.4
Others 2.8

Factors:

Rotary drum; belt/screw or string discharge	1.22
General/paper pulp	2.17-3.38
Mild steel/stainless steel	0.69
Vacuum table mild steel/SS	0.48

Vacuum filter auxilliaries (vac. pump, receivers, etc.), Often ~ 50% of filter cost

Flares
Mild steel, High Btu*, with accessories



Size exponents:

Elevated	0.59
Ground	0.39

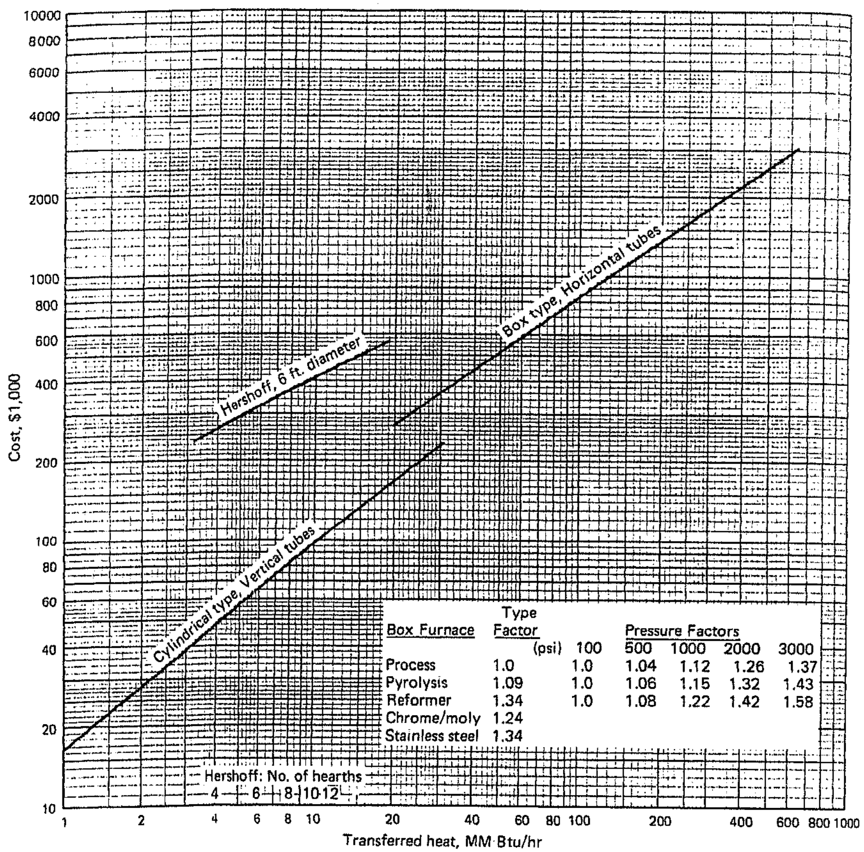
Installation factor 1.45

*High = 1,000; low = 60 Btu/ft³

Factors:

Ground: Low/High* Btu,	0.3
Elevated: Low/High* Btu,	0.8
Corrosive	2.0
Guyed (100 ft.), self-supporting (xelevated)	1.3-1.8

Furnaces
Mild steel tubes



Box Furnace	Type Factor	(psi) 100	Pressure Factors 500	1000	2000	3000
Process	1.0	1.0	1.04	1.12	1.26	1.37
Pyrolysis	1.09	1.0	1.06	1.15	1.32	1.43
Reformer	1.34	1.0	1.08	1.22	1.42	1.58
Chrome/moly	1.24					
Stainless steel	1.34					

Size exponents:

Hershoff	0.48
Box	0.70
Cylindrical	0.78

Installation factor: 1.30–71; avg. 1.52

Module factor: 2.1

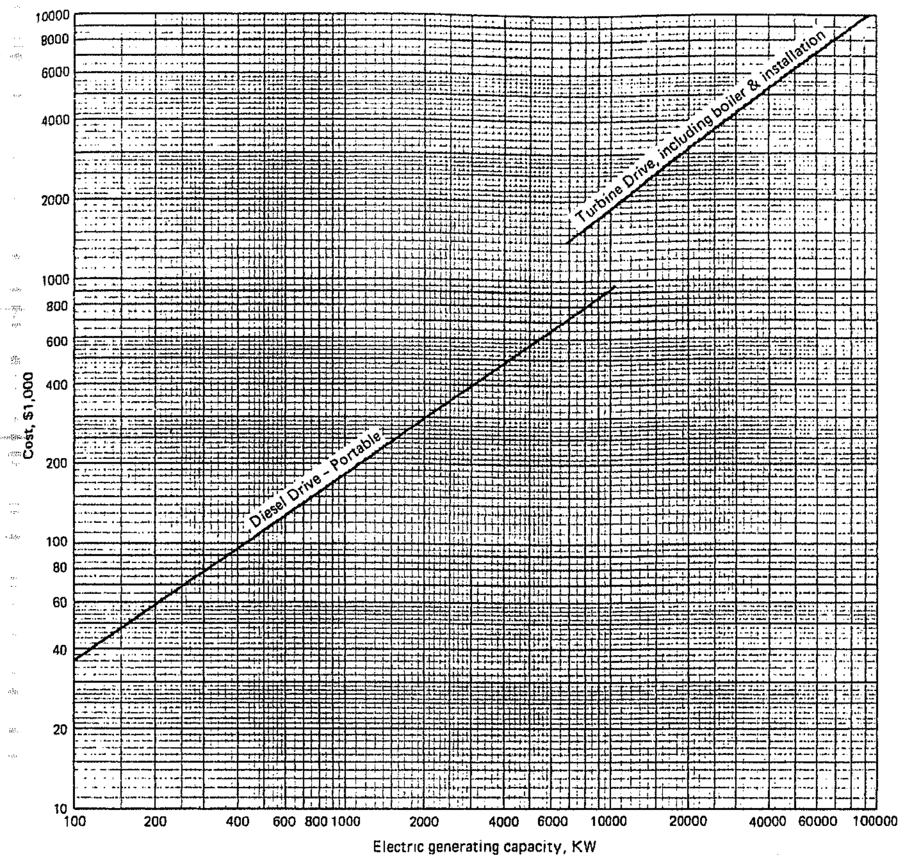
Material factors:

Cylindrical, vertical tubes:

Stainless steel	1.74
Chrome/moly	1.44
with Dowtherm	1.33

Hershoff diameter:
6–19 ft $(D/6)^{0.55}$
>19 $(D/6)^{0.65}$

Generator, Electric Power



Size exponents:

Diesel drive	0.71
Turbine drive	0.76

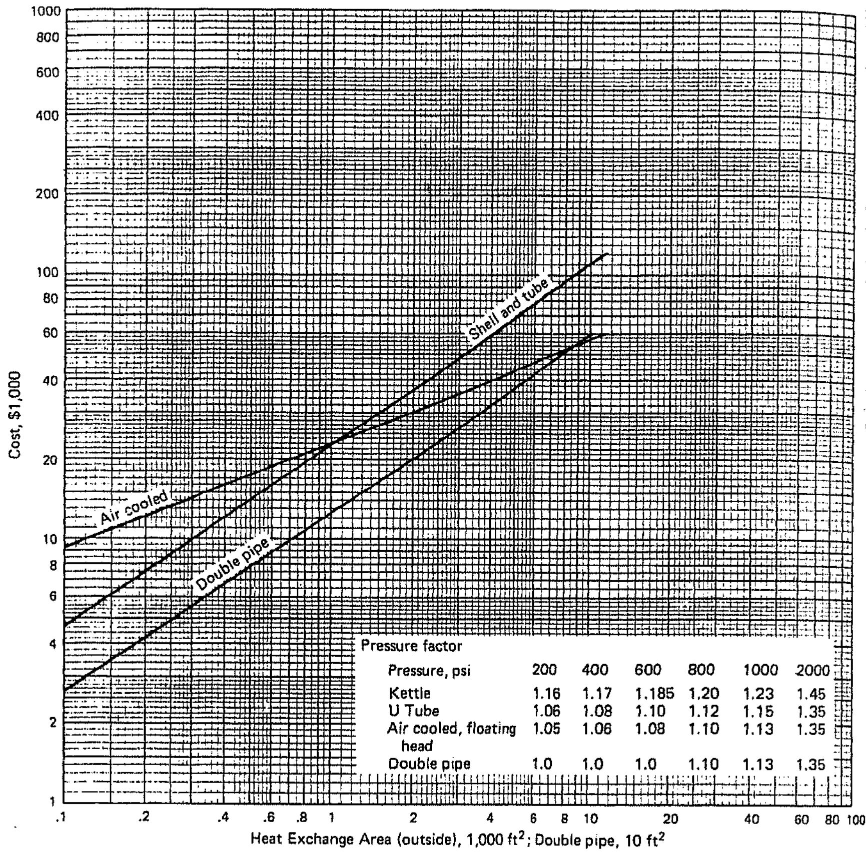
Installation factor:
2.22–2.39
avg. 2.31
Module factor 2.5

Factors:

Gas/diesel engine	1.81
Coal/oil, gas (turbine)	1.29

Heat Exchangers; Shell and Tube, Double Pipe, Air Cooled

Mild steel construction; Shell and tube floating head
150 psig pressure, 3/4 X 1 in. square pitch, 16 ft tubes



Pressure factor

Pressure, psi	200	400	600	800	1000	2000
Kettle	1.16	1.17	1.185	1.20	1.23	1.45
U Tube	1.06	1.08	1.10	1.12	1.15	1.35
Air cooled, floating head	1.05	1.06	1.08	1.10	1.13	1.35
Double pipe	1.0	1.0	1.0	1.10	1.13	1.35

Size exponent

Shell & tube, Double pipe	0.68
Air cooled	0.39

Installation factor

1.23–2.10, avg. 1.61

Module factor

Shell & tube	3.2
Double pipe	1.8
Air cooled	2.2

Other factors: Exchanger type

Shell & tube to:

Kettle reboiler	2.35
U-tube	1.85
Fixed tube sheet	1.79

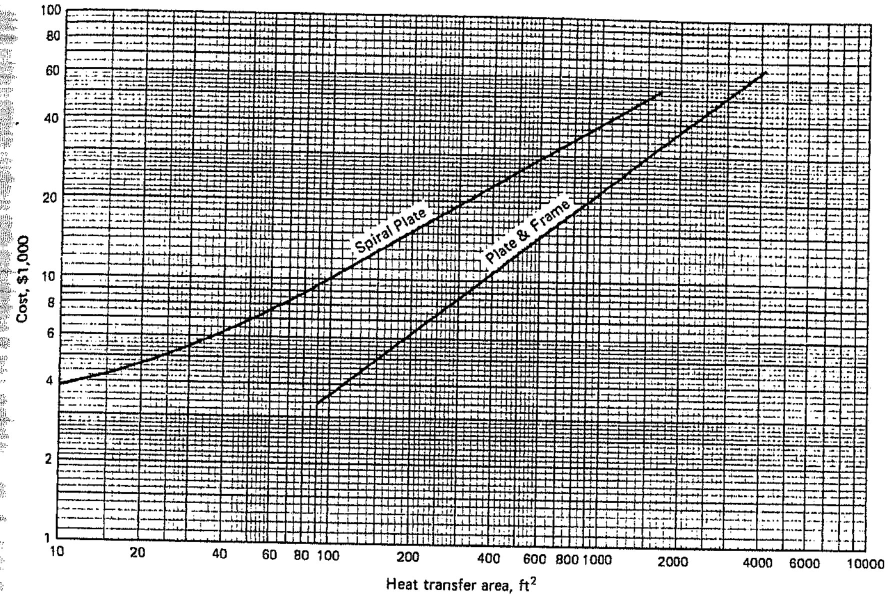
Shell & tube material factor

$a + (a/100)^b$

Shell	Tube	a	b
CS	SS	1.75	0.13
SS	SS	2.70	0.07
CS	monel	2.1	0.13
monel	monel	3.3	0.08
CS	Ti	5.2	0.16
Ti	Ti	9.6	0.06
CS	moly	1.40	0.05
moly	moly	1.67	0.16
CS	Admiralty	1.08	0.05

Heat Exchangers: Spiral, Plate and Frame

304 stainless steel; no insulation



Size exponent:

Plate & frame 0.78

Equations:

Spiral plate: $\$ = 660A^{0.59}$
Plate & frame: $\$ = 100A^{0.78}$

Installation Factor:

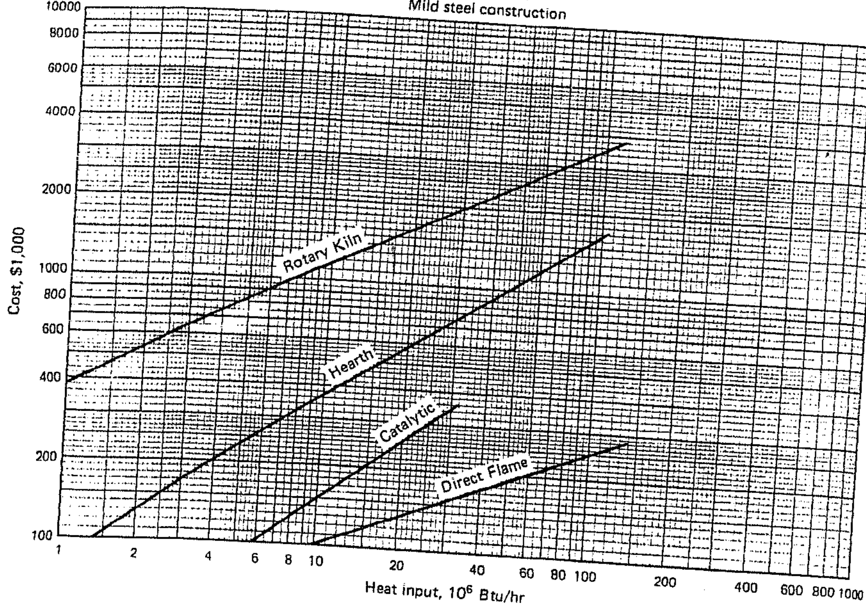
Plate & frame:

Mild steel	1.70
Stainless	1.53

Material Factor:

Mild steel	0.43
316 stainless	1.1
Nickel	1.2
Titanium	2.6

Incinerators
Mild steel construction



Size exponents:

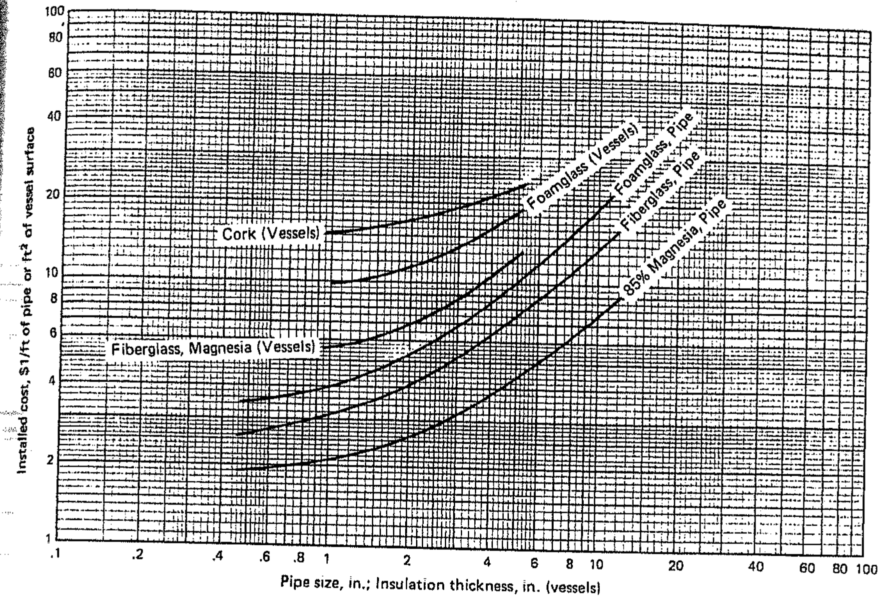
Rotary kiln	0.48
Hearth	0.64
Catalytic	0.75
Direct flame	0.39

Module factor 2.2

Factors:

Corrosive material	1.5
Toxic waste	2.0
316 stainless	2.7
Monel	3.3
Nickel	3.5

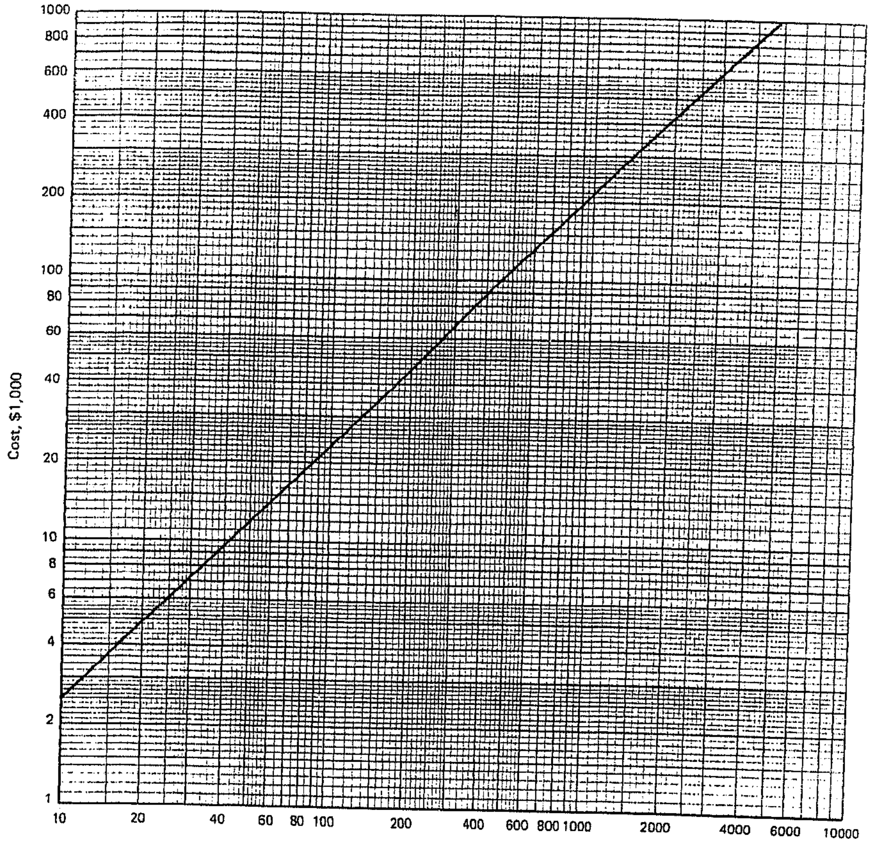
Insulation
2 in. thickness for pipe



Insulation thickness factors for pipe:

3 in.	1.5
1½ in.	0.7
1 in.	0.55
½ in.	0.4

Ion Exchange*
Mild steel construction; 465 ppm removed



Size exponent: 0.97

Module factor 2.0

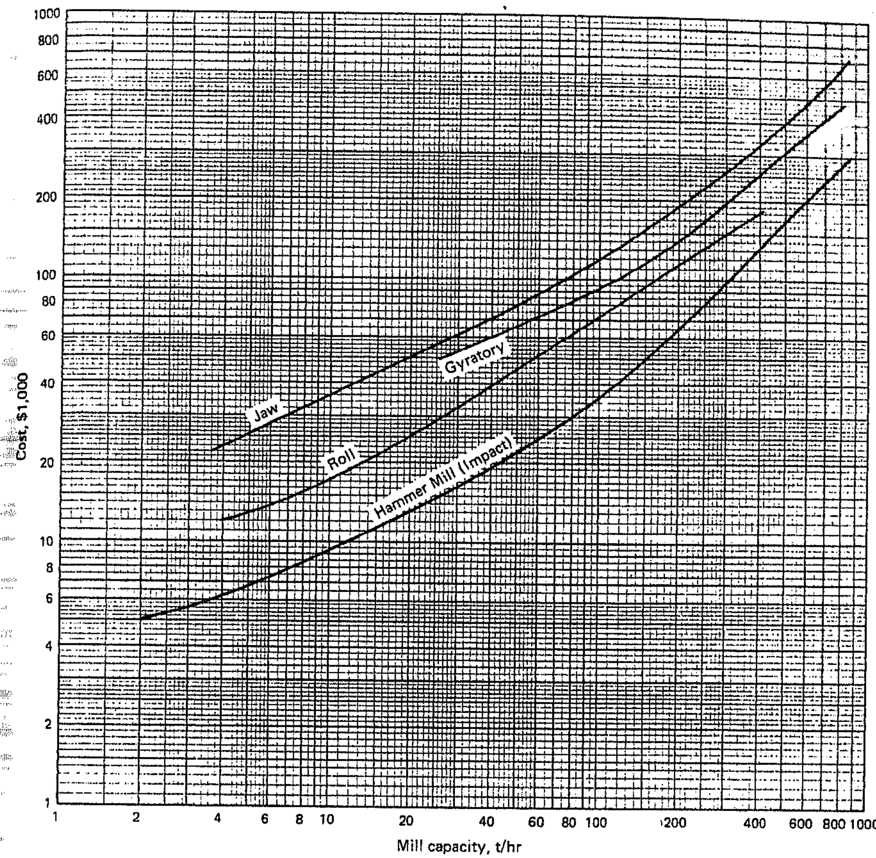
Installation factor:
1.58-65, avg. 1.62

Factor
Ions removed $\left(\frac{\Delta}{465}\right)^{0.51}$

(~35 ppm typical for boiler makeup)
(~320 ppm typical for cooling tower makeup)

*See water treating.

Mills: Hammer, Jaw, Gyratory, Roll Crushers

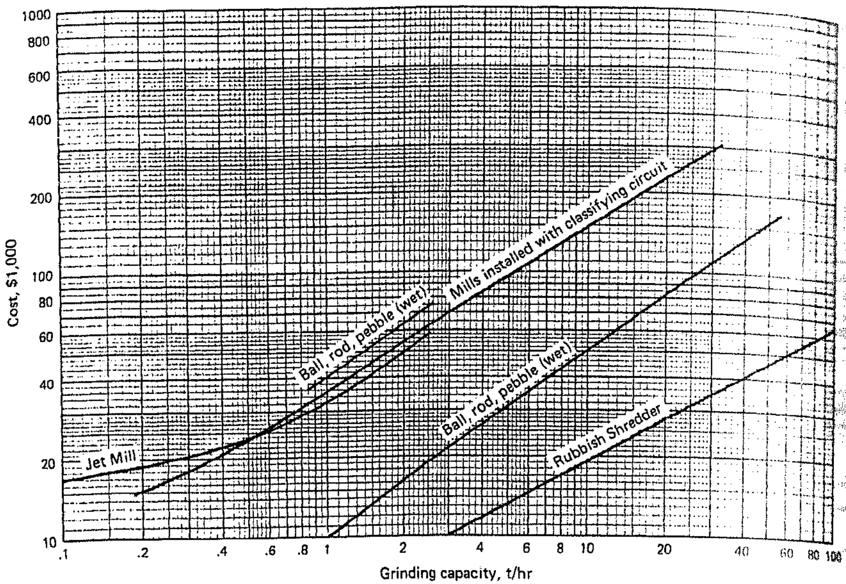


Module factor:
Hammer 2.8
Others 2.1

Installation factor:
1.30-2.15, avg. 1.83

Mills: Ball, Rod, Pebble (Wet), Jet, Rubbish

Reduction ratio 34 (i.e., ~ 1/2 in. - 65 mesh; 3/4 in. - 45 mesh)



Size exponent

Shredder	0.53
Mills; installed	0.62
purchased	0.70

Installation factor:
1.30 - 2.15; avg. 1.83

Modular factor:
1.8 -2.8; avg. 2.3

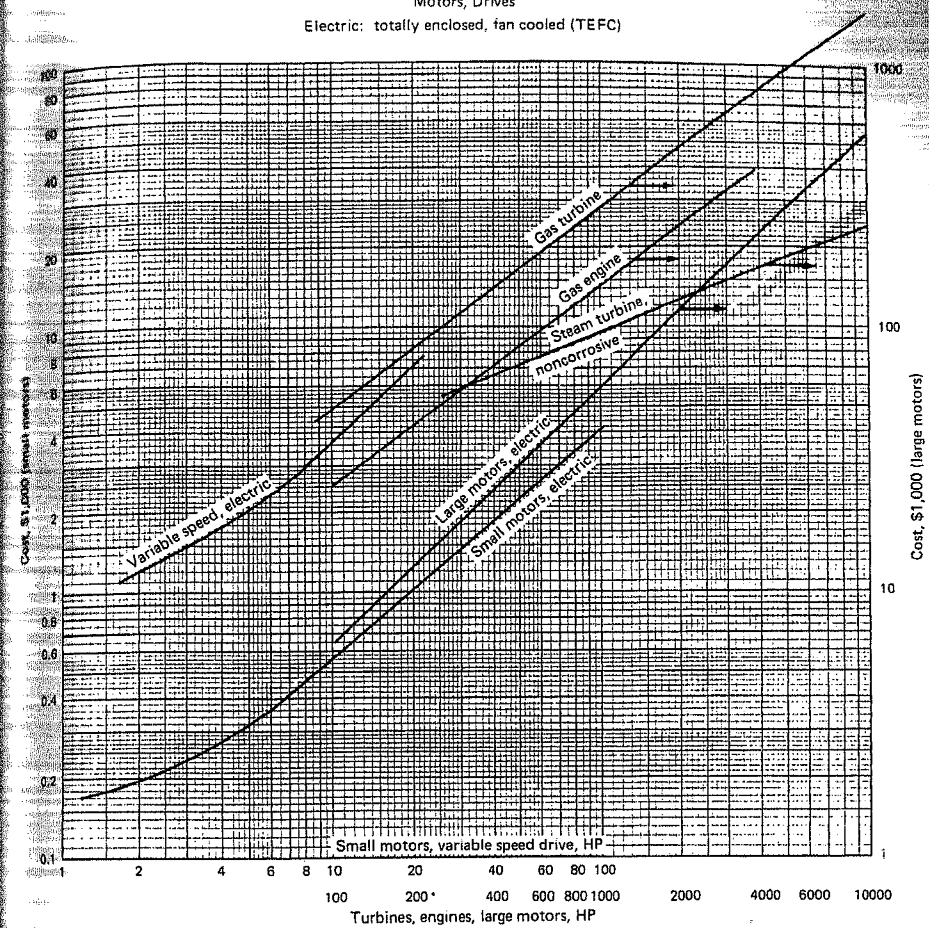
Factors:
Ball, etc. mills
Size reduction

$\left(\frac{\text{Reduction}}{34}\right)^{1.3}$

Dry/wet = 1.25

Motors, Drives

Electric: totally enclosed, fan cooled (TEFC)



Size exponent:

Electric motors, small	0.86
Gas turbine, engine	0.76
Steam turbine	0.41

Module factor:

Electric 2.0 (1.5 on fans, pumps, compressors)
Gasoline 2.0
Gas, steam turbines 3.5

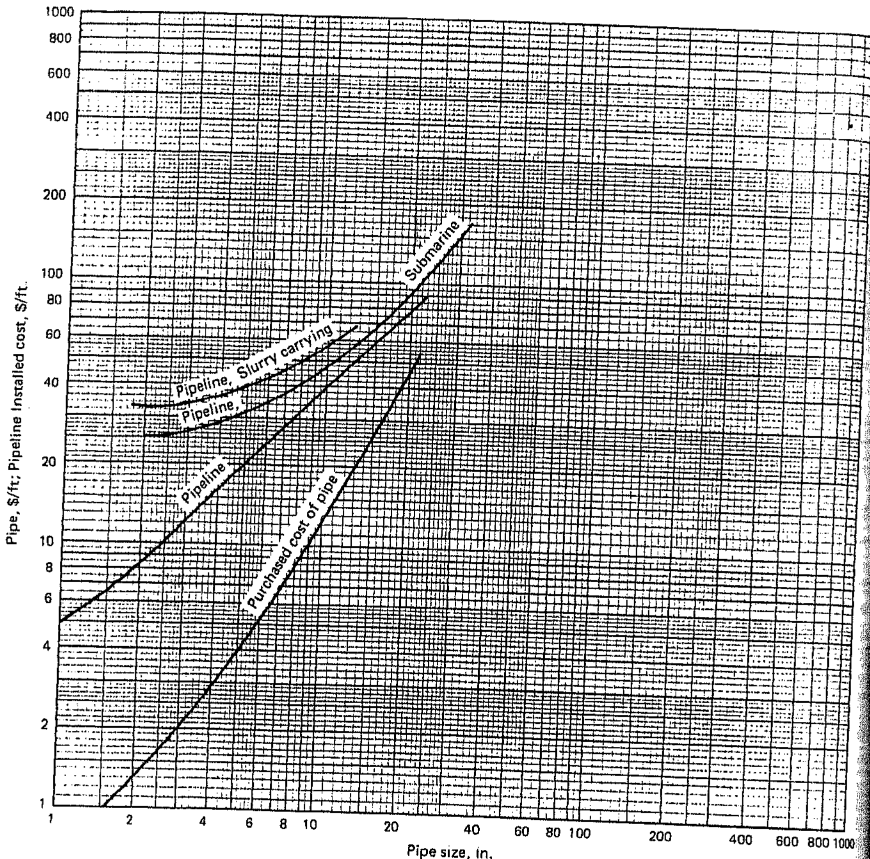
Variable speed drives:

Ratio	Factor
1.5 to 5/1	1.0
6/1	1.08

Factors: Electric motors

Speed, rpm	1800	1.0
	3600	1.04
	1200	1.6
	900	2.6
Construction:	TEFC	1.0
	Explosion proof	1.2
	Drip proof	0.74

Pipe, Pipelines
Mild steel

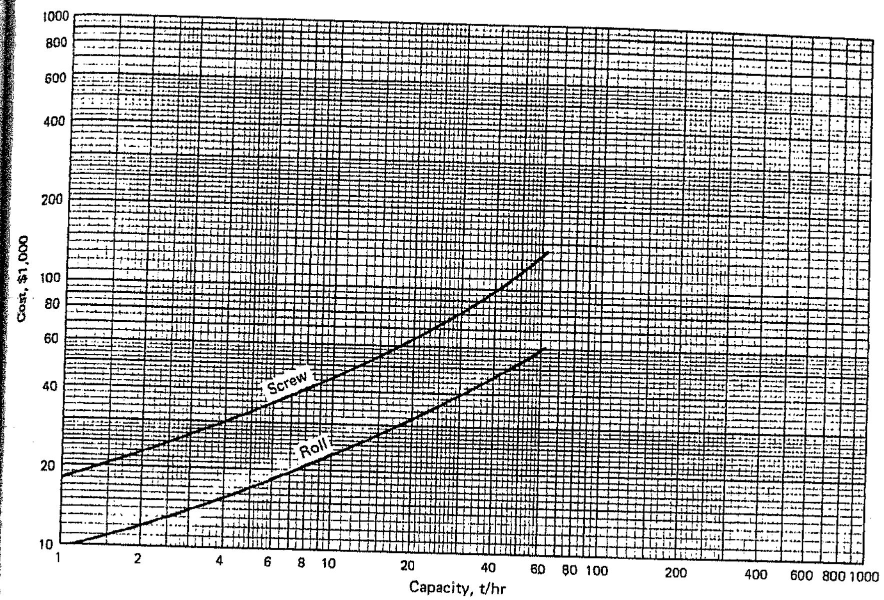


Size exponent:
Pipelines 0.99

Factors:

304 stainless, schedule 10S	
Bare pipe	2.05
Traced, insulated	3.4
Fittings	18
Valves	94

Presses: Roll, Screw
Mild steel construction



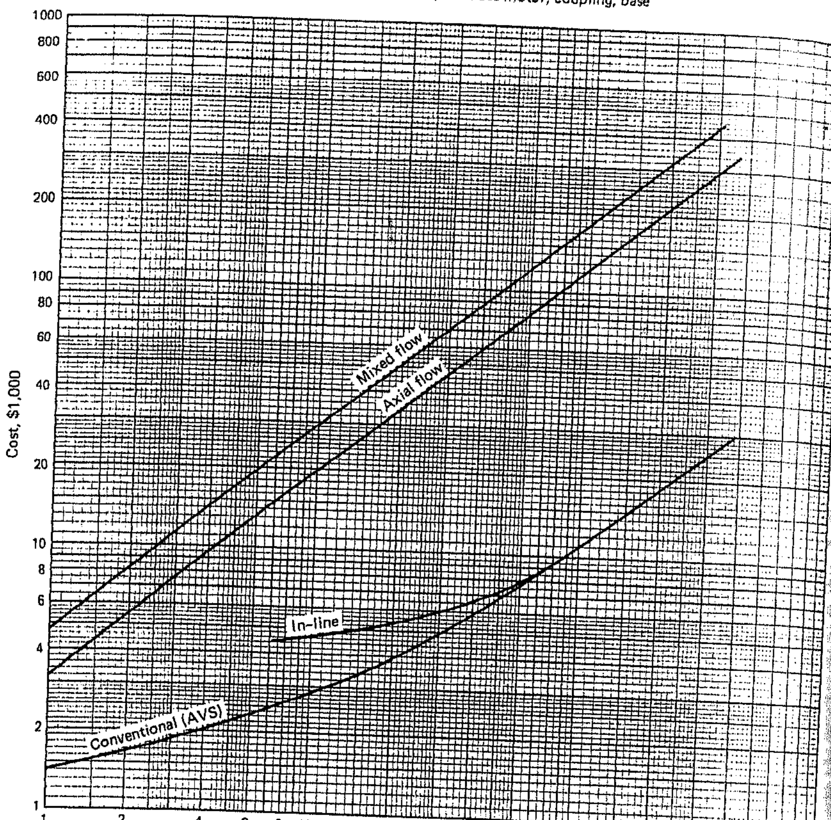
Installation factor: 2.05

Module factor: 2.4

Material factors:

Stainless steel	1.5
Nickle alloy	1.9

Pumps, Centrifugal
Cast iron, horizontal, includes motor, coupling, base



Factors:

	Conven-tional	In-line	Axial Flow	Mixed Flow
Size exponent			0.79	0.79
Installation	1.30	1.27	1.58	1.32
Module factor	1.5	1.75	2.05	1.70
Cast steel	1.4	1.3		
316 stainless	2.0	1.6		
Copper alloy	1.3			
Nickel alloy	3.6			
Titanium	5.7			

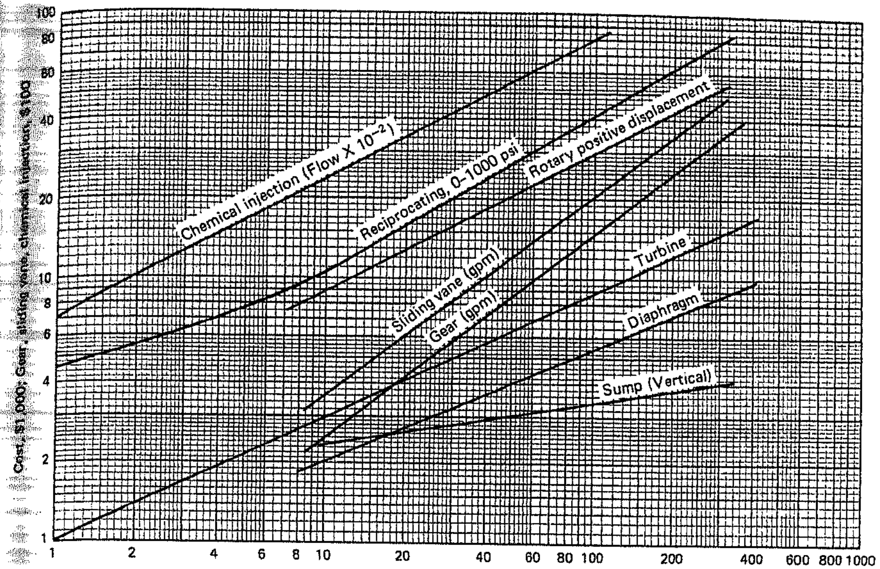
Pressure factor:

	to 150 psi	150-500 psi	500-1000 psi
In-line	1.00	1.48	1.92
Conventional	1.0	1.62	2.12

Factors:

Conventional: APS/AVS = 1.6
In-line: vertical/horizontal = 0.89
Mixed, axial flow: vertical/horizontal = 1.12

Pumps, Miscellaneous
Mild steel construction



Factors

	Reciprocating	Turbine	Chemical Injection
Size exponent	0.59	0.47	0.52
Installation		1.38	1.58
Module factor	3.3	1.80	2.83
Cast iron	1.0		1.0
Cast steel	1.8		1.25
Stainless	2.4		1.95
Nickel alloy	5.0		
0-150 psi	1.0		1.0
150-500	1.32		1.37
500-1000	1.53		1.79

General installation factor:
1.25 - 2.40; avg. 1.74

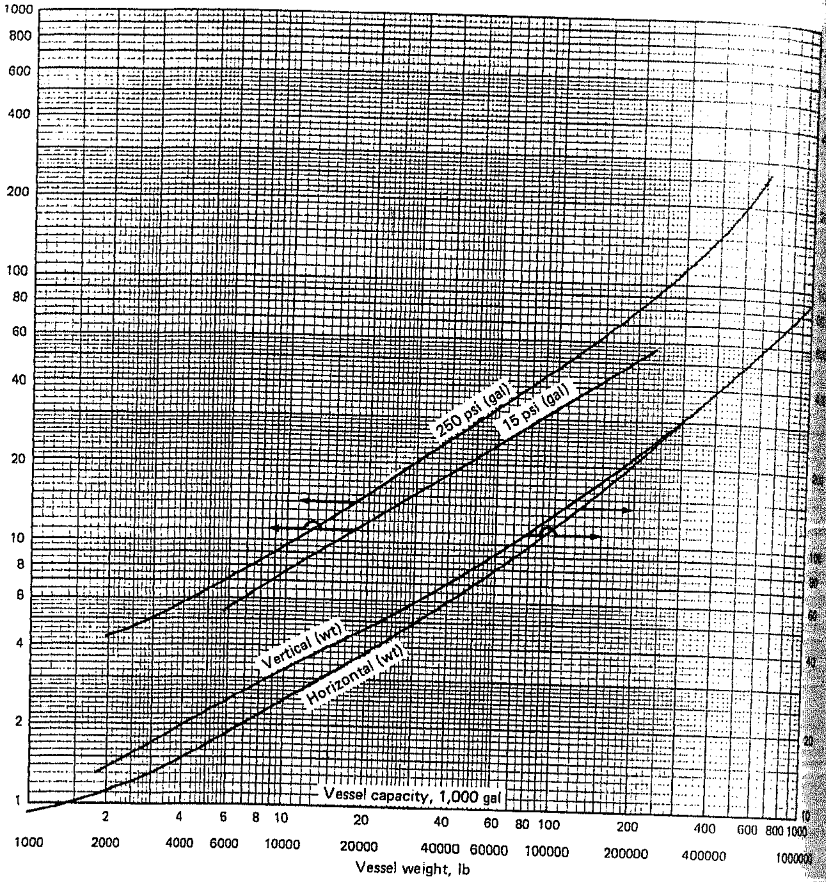
Other size exponents:

Diaphragm	.43
Rotary	.52
Gear	.76
Sump	.15

Factors:

Reciprocating: ΔP (1,000 - 5,000)/(0 - 1,000) = 3.8
Sump: 3600/1800 rpm = 1.2
1200/1800 in. = 1.5
Chemical injection: Fixed/variable speed = 1.67

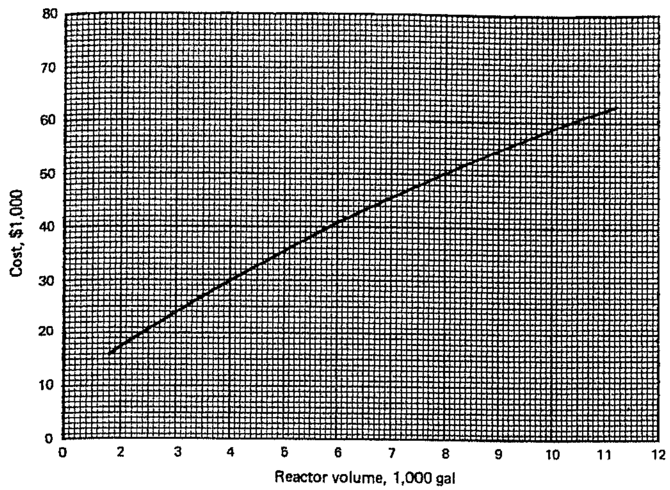
Pressure Vessels*
Mild steel construction



Size exponent:
15 psi (gal) 0.64

*See columns for pressure and material correction factors.

Reactors*
304 stainless steel; jacketed; no agitation



Module factors:

Stainless	1.8
Glass lined	2.1
Mild steel	2.3

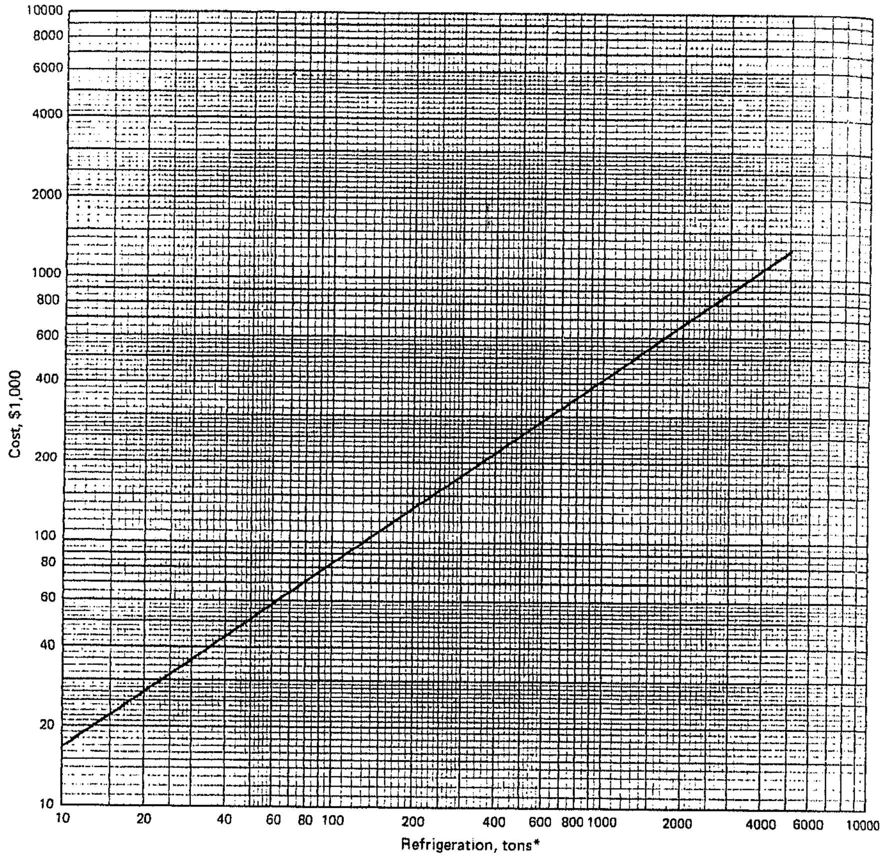
Installation factor:
1.40 – 2.10; avg. 1.70

Material factors:

316 stainless	1.2
Glass lined	.8
Lead lined	.7
Mild steel	.6

*See agitated tanks.

Refrigeration
40°F temperature



Size exponent 0.69

*One ton = 12,000 Btu

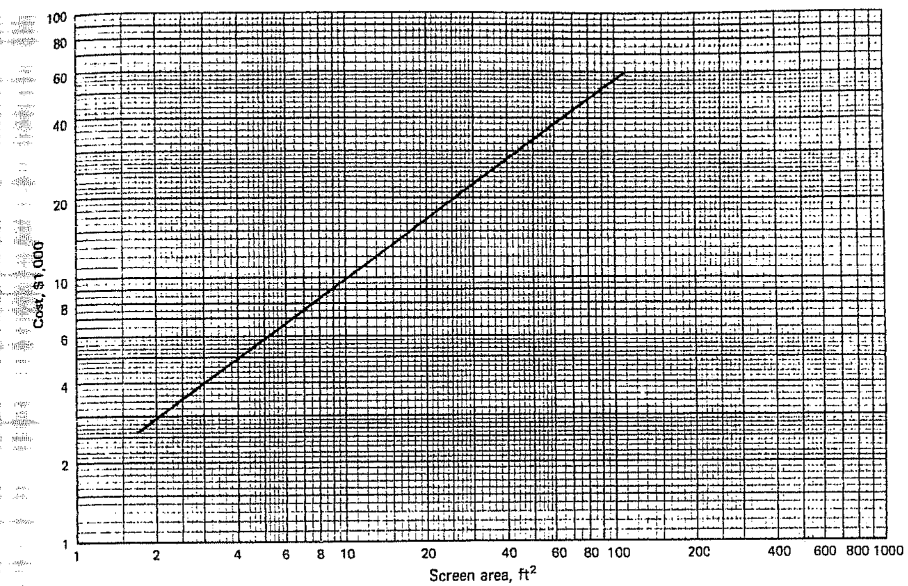
Installation, Module factor

1.38–53; avg. 1.46

Evaporative temperature factors:

+20F	1.5
0	1.9
−20	2.4
−40	3.5

Screens, Vibrating
Mild steel, single deck



Size exponent: 0.75

Module factor: 2.8

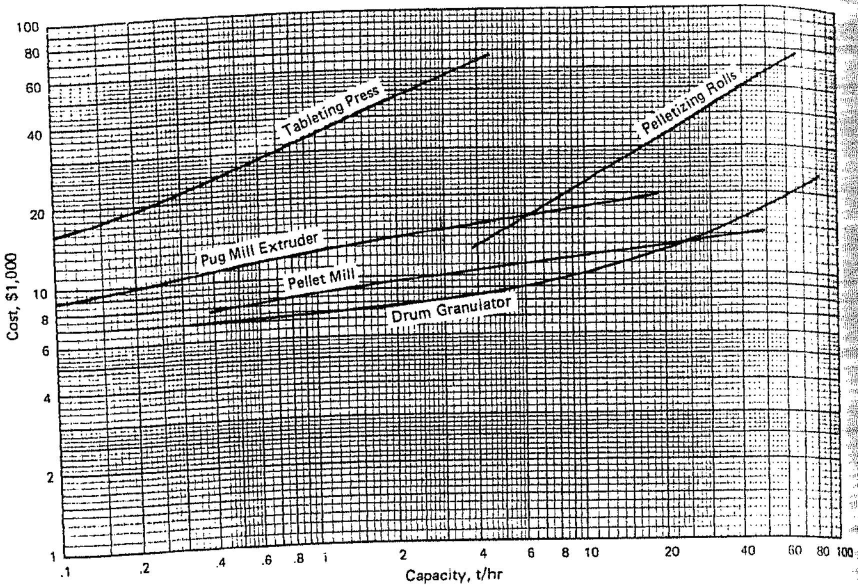
Installation factor:

1.45–2.27; avg. 1.85

Factors:

Double deck	1.6
Stainless steel	1.25
Nickel alloy	1.8

Size Enlargement
Mild steel construction



Size exponent

Pug mill	0.15
Pellet mill	0.12
Pelletizing rolls	0.58

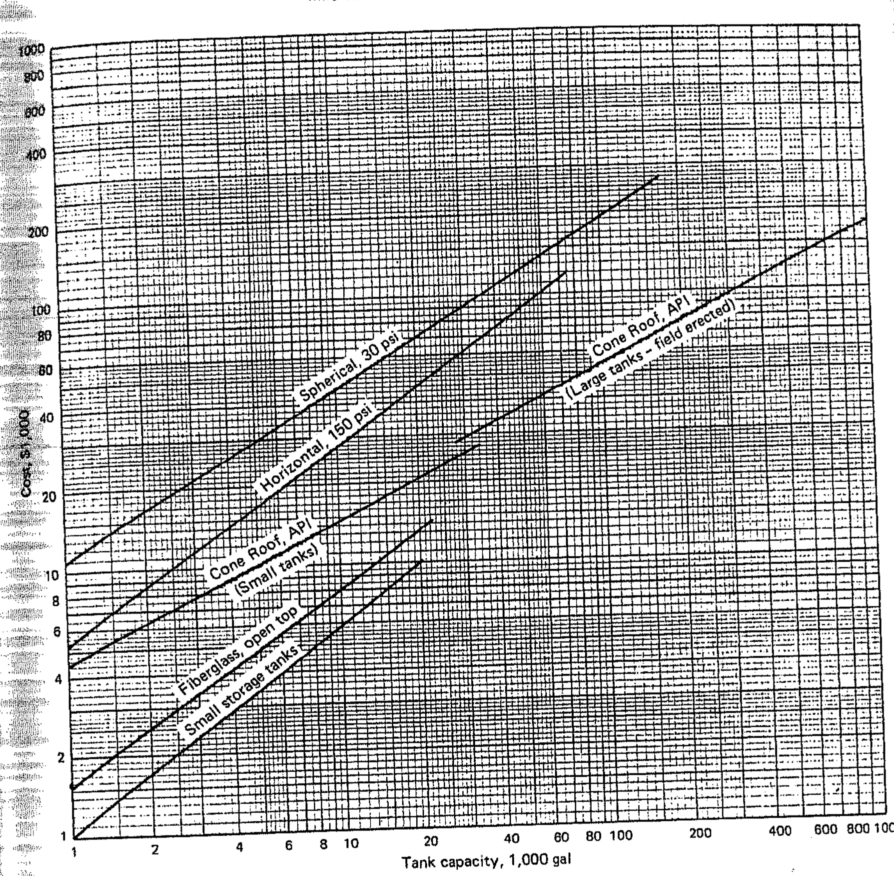
Installation factor: 2.05

Factors

	Pug mill extruder	Disk, drum granulator	Others
Module factor	2.2	2.8	2.05
Stainless steel	1.2	1.1	1.2
Nickel alloy	1.4	1.3	1.4

Screw/pug mill extruder	5.6
Disk/drum granulator	0.68

Tanks
Mild steel construction unless otherwise noted



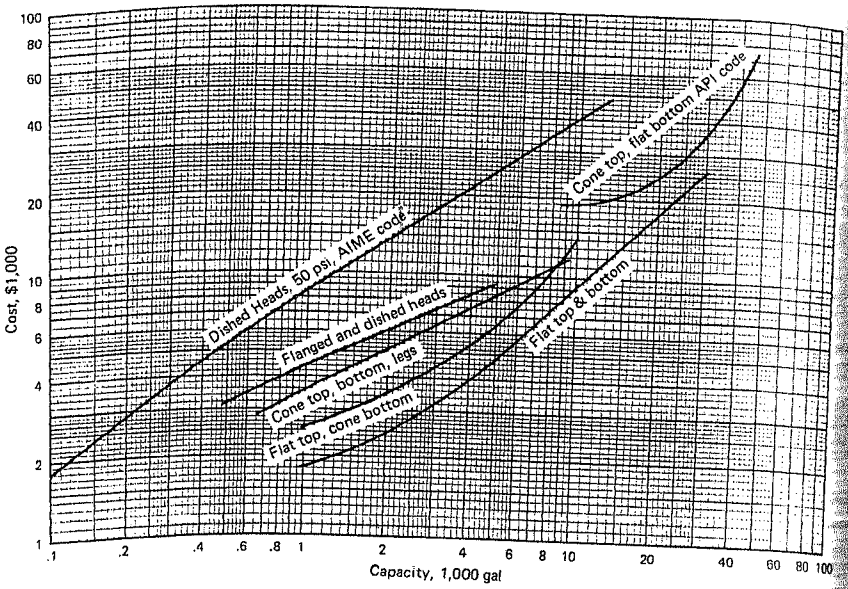
	Size exponent	Module factor	Pressure factor				
Small cone top	0.51	1.6					
Large cone top	0.51	1.9					
Horizontal, pressure	0.72	2.08	200 1.18	250 psi 1.38			
Sphere	0.62	1.87	50 1.08	75 1.19	100 1.26	125 2.39	200 1.53
Fiberglass	0.71						
Small storage	0.71						

Factors:

Rubber lined	1.5
Lead lined	1.6
Stainless	2.0
Floating roof; large, field erected	1.8

Installation factor:
1.20 – 2.30. avg. 1.88

Tanks, (Small)
304 stainless steel



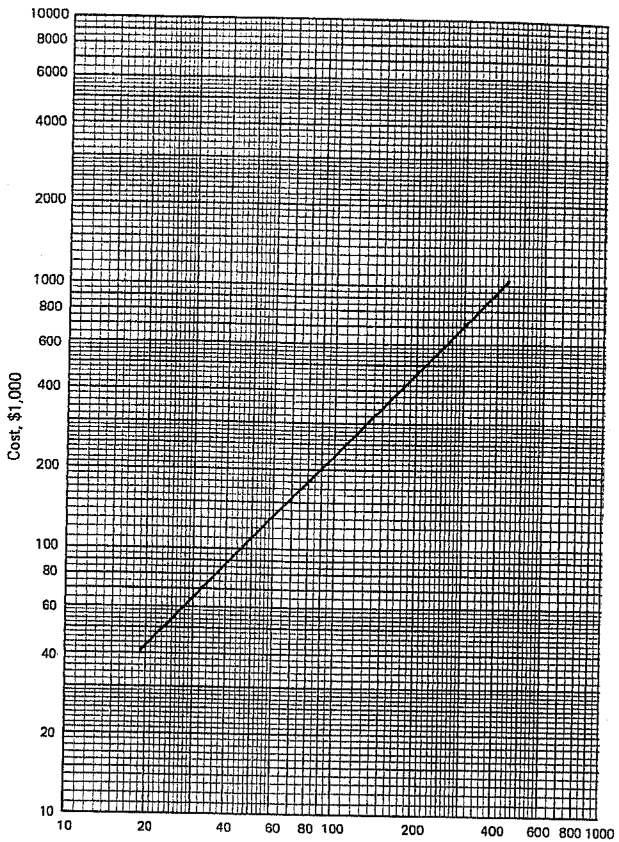
Size exponent

Dished head, 50 psi	0.68
Flanged, dished head	0.48
Cone top, bottom, legs	0.57
Flat top, bottom	0.93

Factor

316/304 stainless steel 1.39

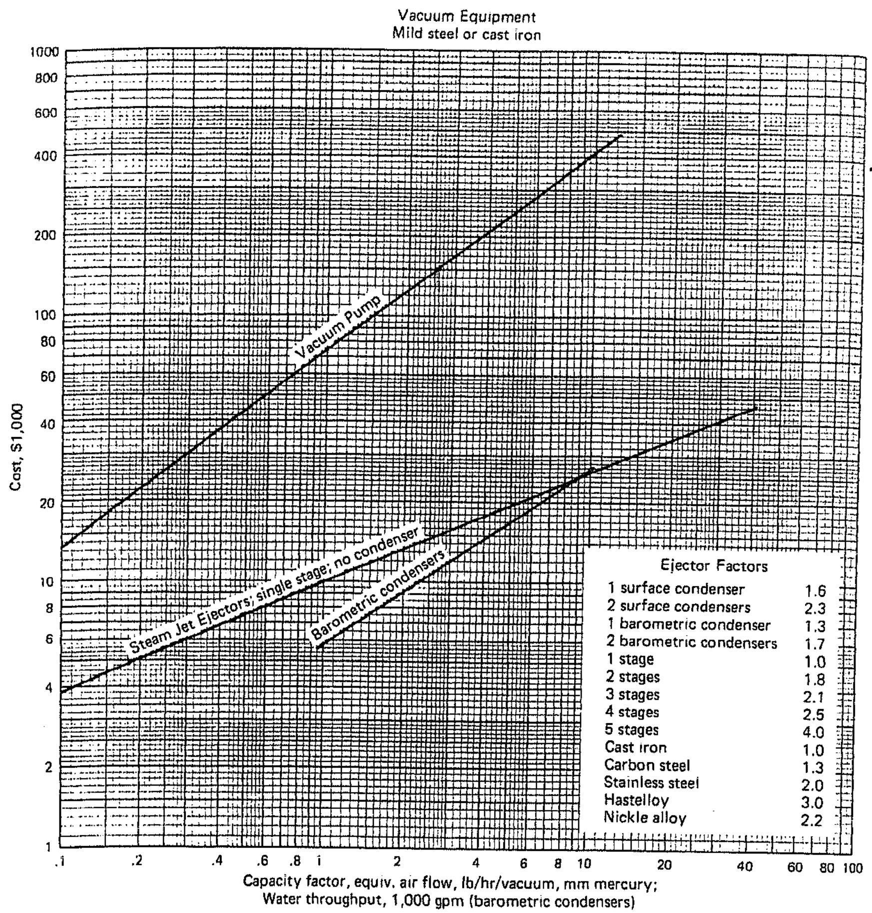
Thickeners, Clarifiers
Rake mechanism, concrete tank, drive



Size exponent: 1.03
Installation factor:
1.63–2.61; avg. 2.12

Module factor: 3.0

Tank factor:
Concrete/steel 0.7 for
units under 40 ft diameter



Size exponents:

Vacuum pumps	0.75
Steam jet ejectors	0.42
Barometric condensers	0.67

Installation factor	1.12
Module factor	2.2

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APPENDIX 2

COMPLETE PLANT COST ESTIMATING CHARTS

The following charts indicate the complete cost of plants to produce various chemicals in differing tonnages. The information has been assembled primarily from four sources: (1) curves on 54 plants published by Guthrie (1974), (2) curves on 18 plants published by *Chemical Engineering* (1973/1974), (3) 33 nomographs, and about 140 single plant size-cost data notations by Kharbanda (1979), and (4) several hundred recent plant construction notices in *Chemical Engineering*'s *Construction Alert*. The first three sources are quite old, with most of the information gathered from the mid-60s through the early 70s. The last source was data from 1980 through 1987. Each source was inflation-corrected to 1987 (CE Index of 320) by means of the *Chemical Engineering* (CE) Index.

The first two references were probably quite authoratative when published, and represented contractor prices for that plant alone, plus the necessary raw material and product storage. The infrastructure for a ''grass roots'' plant, or even for minor utility and other required nonplant facilities was not included. The later two sources, on the other hand, are basically press-release information stating what the complete facility cost. This might include land, site development, and/or any of the infrastructure required to make the plant function. Costs would thus be higher, and the assembled data would be much more scattered because of each location's different requirements.

Both factors, the early data's age, and the most recent data's complete cost basis, tend to limit the accuracy of the plots. When considerable data were available, high, low and average lines were shown. Presumably the high values represent more infrastructure requirements. When only one data point (i.e., one plant cost at one size) was available, the capacity versus cost line was drawn with a slope of 0.64, the average size-cost exponent of Guthrie's 54 plants.

Normally it should be expected that the costs shown in these plots should be roughly correct, and perhaps on the high side. However, some of the data from the first three references appear to be very low, so caution should be used with all of the charts. They may be useful as a guide, but not too much confidence should be placed in their accuracy. The basis for the costs should be considered as a reasonably high value for the plant alone, plus storage, and the CE Index 320.