A COMPILATION OF COST INFORMATION FOR CONVENTIONAL AND ADVANCED WASTEWATER TREATMENT PLANTS AND PROCESSES

by

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Cincinnati, Ohio
December, 1967

UNITED STATES
DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
MEMORANDUM

IN REPLYING ADDRESS:

OHIO BASIN REGION
4676 COLUMBIA PARKWAY
CINCINNATI, OHIO 45226

February 8, 1968

TO: FWPCA Regional Public Information Officers
U.S. Department of the Interior

FROM: Chief, Office of Information
Ohio Basin Region, FWPCA
Cincinnati, Ohio 45226

SUBJECT: "A Compilation of Cost Information for Conventional and Advanced Wastewater Treatment Plants and Processes," by Robert Smith December 1967

This memorandum transmits one copy of the subject report for your information. Additional copies are available upon request to this office.

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FOREWORD

The cost associated with building and operating wastewater treatment plants or individual wastewater processes has always been difficult to estimate for planning purposes. This is particularly true if the cost of the process must be related to the effectiveness of the process in removing water contaminants such as BOD, nitrogen, or phosphorus. Many cost studies are available from the literature or from government sponsored research but the individual engineer often has access to only a limited number of these studies. Assumptions made in these studies and the cost items included or omitted often vary with the amount of effort invested in the study or the background and interests of the person conducting the study. A great deal of information is available, however, and this report is an effort to bring together in one place most of the useful information now available using a consistent set of assumptions and omissions for the purpose of producing a working document useful to engineers and scientists working in the field of wastewater treatment.

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COST OF ADVANCED WASTEWATER TREATMENT PROCESSES

1. Solids Removal by Coagulation and Sedimentation
2. Filtration Through Sand or Graded Media
3. Ammonia Stripping
4. Granular Carbon Adsorption
5. Electrodialysis
6. Microstraining of Secondary Effluent
7. Aeration of Secondary Effluent
8. Chlorination of Secondary Effluent
9. Pipelines for Ultimate Disposal

CONSTRUCTION COST OF INDIVIDUAL EQUIPMENT, STRUCTURES, & CONSUMABLE ITEMS

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COST OF CONVENTIONAL WASTEWATER TREATMENT PLANTS

Total construction costs and operating and maintenance costs were taken from six principal sources.[1-6] Regression relationships from these six sources are shown in Figures 1, 2, 3, and 4. For the three types of conventional plants, the total cost of treatment in cents per thousand gallons is given in Figures 5, 6, and 7. Field construction costs reported by Logan et al.[1] represent the total bonded cost for construction of the plant excluding ancillary works such as interceptors, outfalls, or pumping stations. Plant construction costs reported in PHS No. 1229[2] and Velz[3] and Diachishin[4] exclude ancillary works and also exclude preliminary expenses such as engineering and legal fees, land acquistion, interest during construction, etc. Both Velz[3] and PHS No. 1229[2] state that costs reported represent about 80% of the total bonded cost for plant construction. Since the total bonded cost for plant construction is required in estimating the total cost of wastewater treatment in cents per thousand gallons the construction cost data given in references 2, 3, and 4 were multiplied by a factor of (1.25) to make them equivalent to the construction cost data given by Logan et al.[1]

Logan[1], Velz[3], and Diachishin[4] used the Engineering News Record Construction Cost Index to adjust all data collected to a specific point of time. It is generally conceded, however, that the ENR Construction Cost Index is too heavily weighted in favor of the cost of common labor. Skilled labor which represents a significant part of the construction cost has not increased in cost at as great a rate as common labor over the past 20-30 years. The ENR Building Cost Index (Table A-I) or the PHS Sewage Treatment Cost Index[7] (Table A-II) are believed to give a more realistic representation of the increase in construction cost with time. For this reason the PHS Sewage Treatment Cost Index[7] was used to adjust data from references 1, 2, 3, and 4 to June, 1967 level.

Total plant construction costs adjusted to June, 1967 taken from references 1-4 are shown plotted in Figure 1. The values given represent national averages. The greater cost estimates are given by Logan[1] and Velz[3] and the smaller cost estimates are given by PHS No. 1229[2] and Diachishin[4]; the ratio of the two is about (1.6) for the activated sludge plants. For the primary plants the Logan[1] data is the greatest and Velz[3] data is the smallest; the ratio is about (1.7). The Diachishin[4] data and the PHS No. 1229[2] data fall in between these extremes. Mean values for construction cost taken from Figure 1 are shown plotted in Figures 4 and 5.

Operating and maintenance data from three sources (references 1, 5, and 6) are shown plotted in Figure 2. The U.S. Department of Labor Average Earnings for Nonsupervisory-Workers in Water, Steam, and Sanitary Systems[8] (Table A-IV) was used to adjust all operating and maintenance costs to the June, 1967 level. It can be seen from Figure 2 that the three sources agree well; the spread is only 10-20%. Mean values from Figure 2 were used in preparing Figures 4 and 5.

Total construction cost for trickling filter plants taken from references 1, 2, 3, and 4 are shown plotted in Figure 3. An average of these data was used in preparing Figure 7. Operating and maintenance cost for trickling filters from two sources are shown plotted in Figure 4. A mean of this data was used in preparing Figure 7.

As shown in Figure A-I from Division of Pollution Surveillance, FWPCA the cost of borrowing money to finance water treatment facilities has been increasing over the last couple of years. Since bonds are sold on the open market, the cost of borrowing money varies with the type of bonds sold and with the financial rating of the municipality issuing the bonds.[9] 4 1/2% interest, believed to be an average conservative value,was used in computing the amoritization cost of all construction. The correct amoritization period to use is also

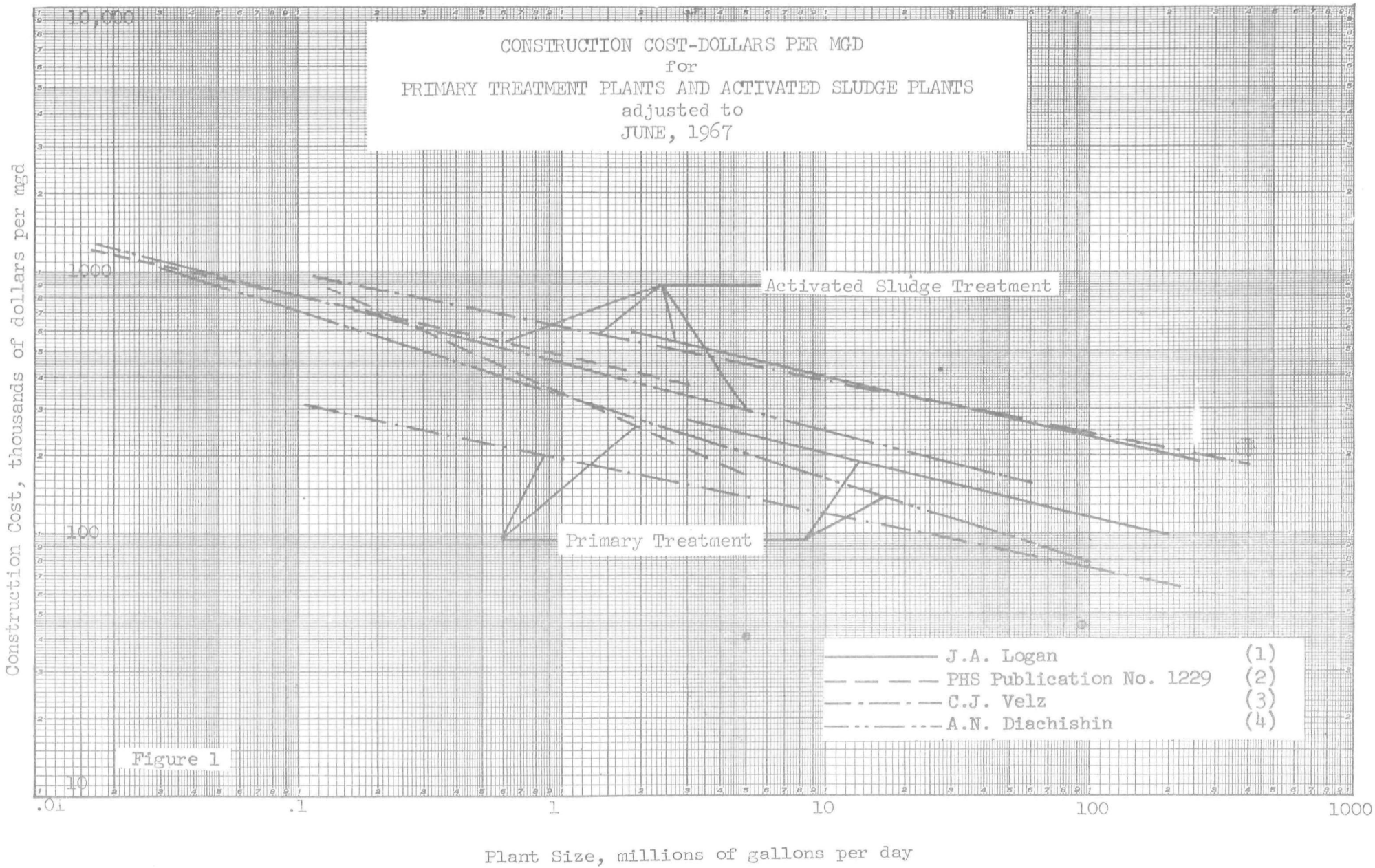

CONSTRUCTION COST-DOLLARS PER MGD
for
PRIMARY TREATMENT PLANTS AND ACTIVATED SLUDGE PLANTS
adjusted to
JUNE, 1967
Activated Sludge Treatment
Primary Treatment
J.A. Logan (1)
PHS Publication No. 1229 (2)
C.J. Velz (3)
A.N. Diachishin (4)
10,000
1000
100
10
.01
.1
1
10
100
1000
Construction Cost, thousands of dollars per mgd
Plant Size, millions of gallons per day

Figure 1

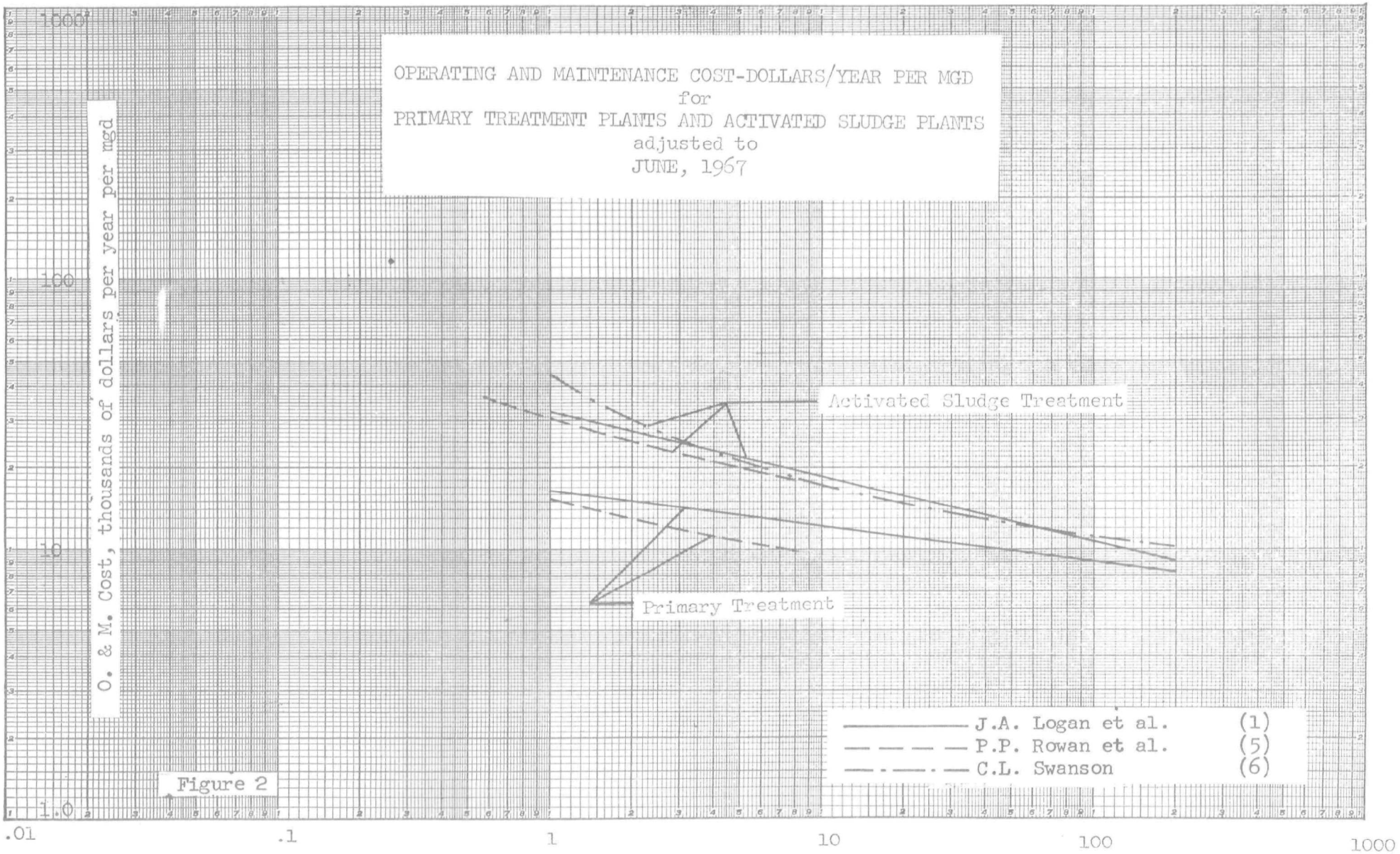

OPERATING AND MAINTENANCE COST-DOLLARS/YEAR PER MGD
for
PRIMARY TREATMENT PLANTS AND ACTIVATED SLUDGE PLANTS
adjusted to
JUNE, 1967
O. & M. Cost, thousands of dollars per year per mgd
1000
100
10
1.0
Activated Sludge Treatment
Primary Treatment
J.A. Logan et al. (1)
P.P. Rowan et al. (5)
C.L. Swanson (6)
.01
.1
1
10
100
1000
Plant Size, millions of gallons per day

Figure 2

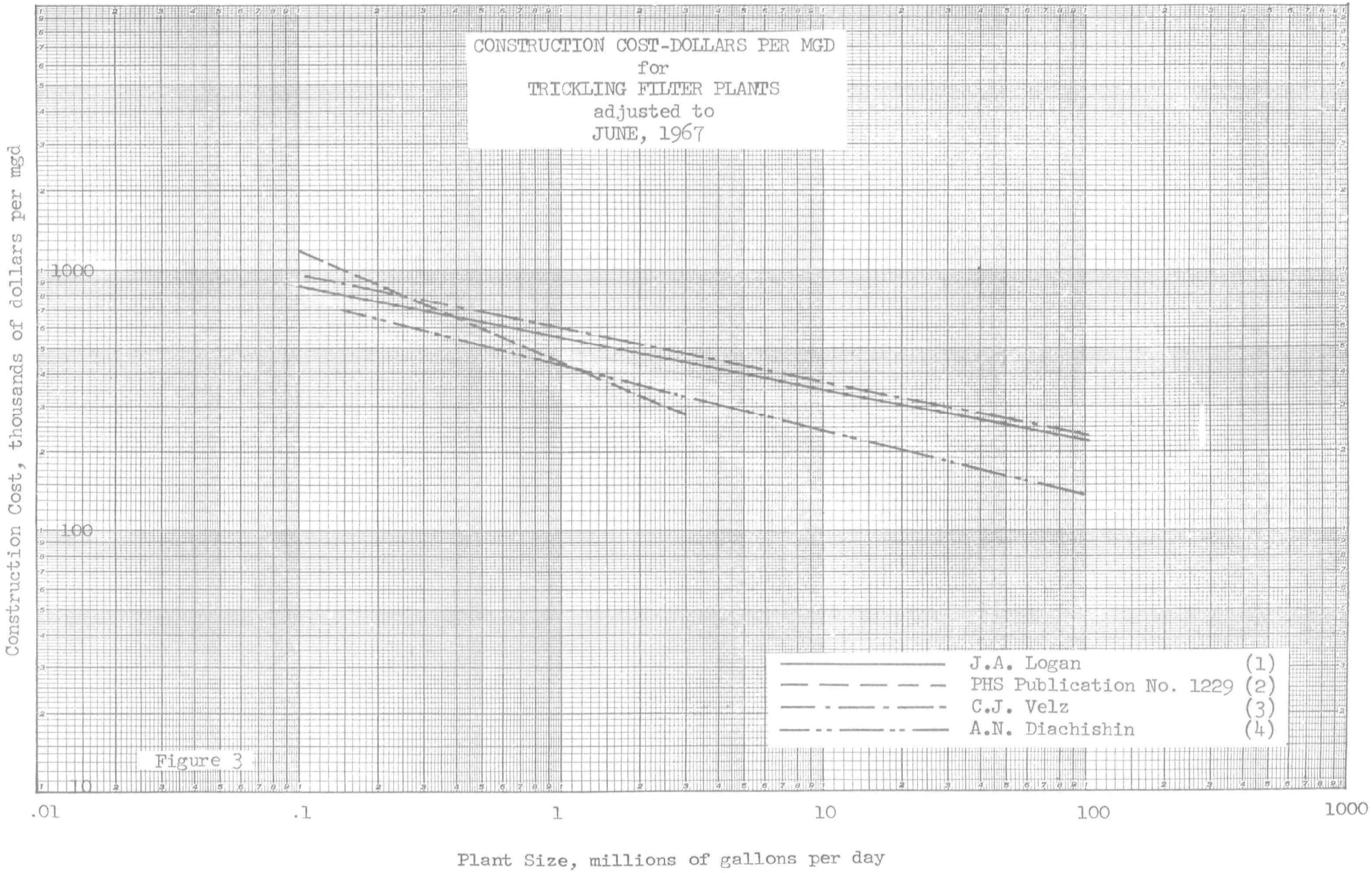

CONSTRUCTION COST-DOLLARS PER MGD
for
TRICKLING FILTER PLANTS
adjusted to
JUNE, 1967
Construction Cost, thousands of dollars per mgd
1000
100
10
.01
.1
1
10
100
1000
Plant Size, millions of gallons per day
J.A. Logan (1)
PHS Publication No. 1229 (2)
C.J. Velz (3)
A.N. Diachishin (4)

Figure 3

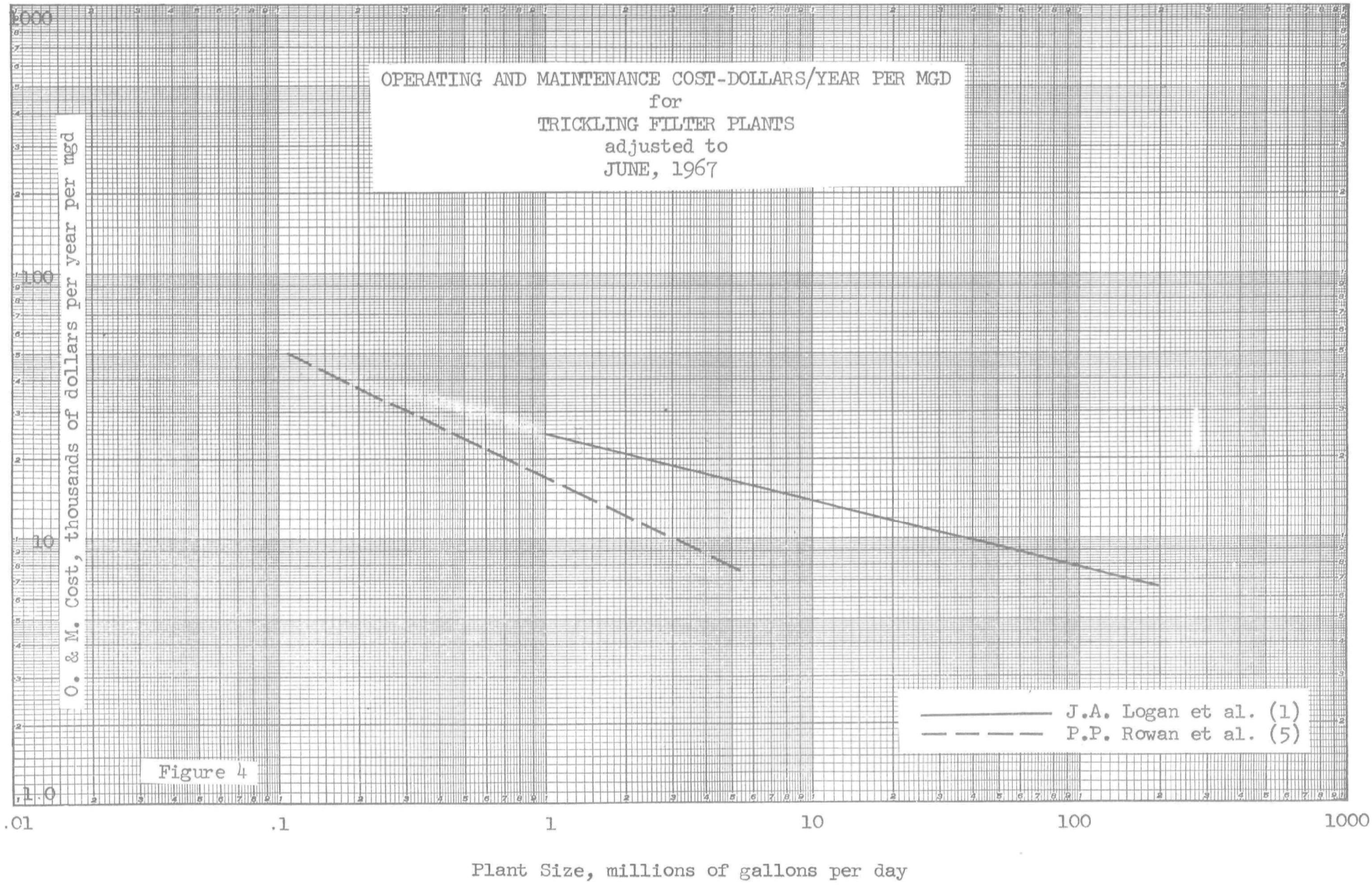
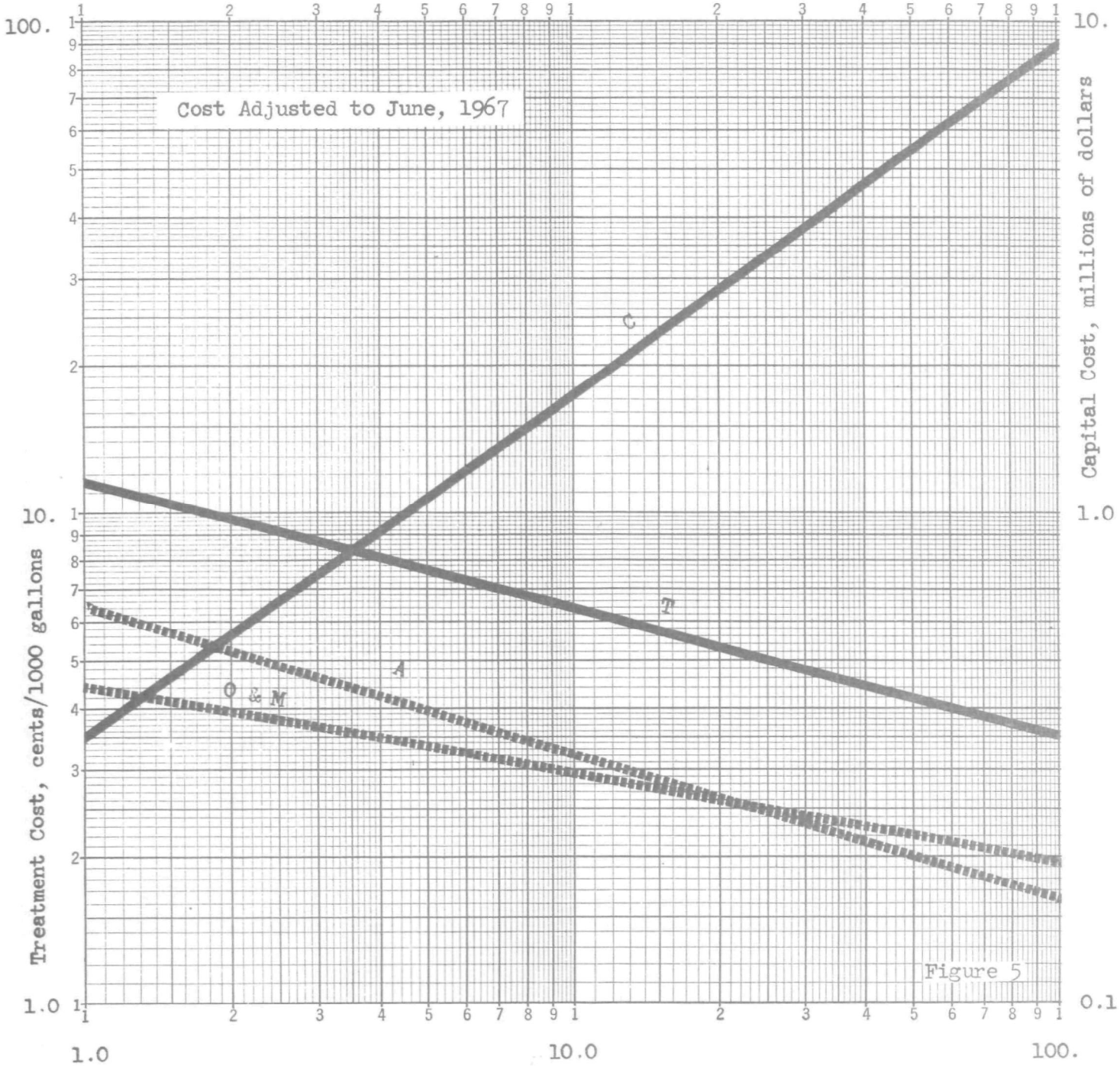

OPERATING AND MAINTENANCE COST-DOLLARS/YEAR PER MGD
for
TRICKLING FILTER PLANTS
adjusted to
JUNE, 1967
O. & M. Cost, thousands of dollars per year per mgd
1000
100
10
1.0
.01
.1
1
10
100
1000
Plant Size, millions of gallons per day
J.A. Logan et al. (1)
P.P. Rowan et al. (5)

Figure 4

PRIMARY TREATMENT PLANTS

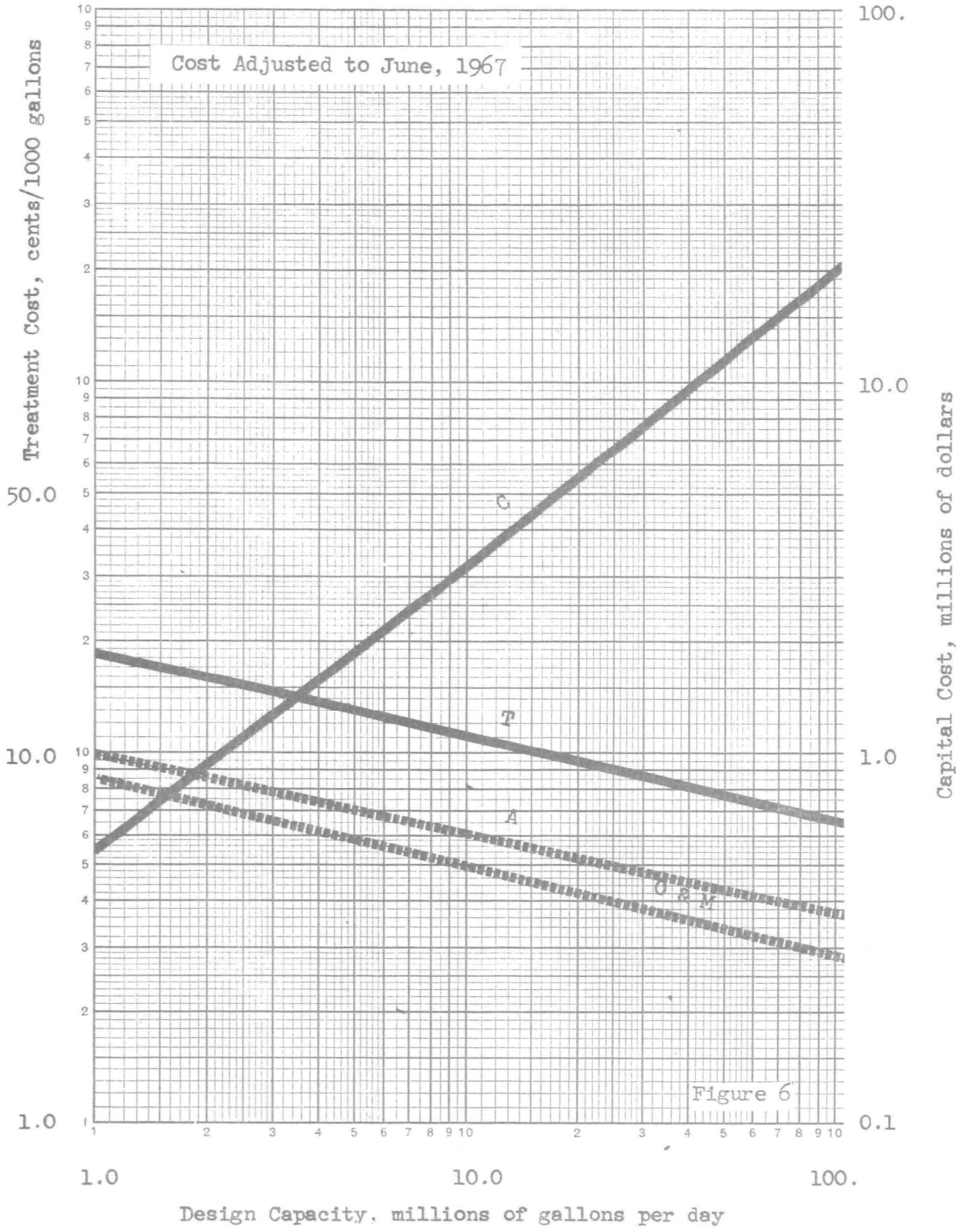
Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

ACTIVATED SLUDGE PLANTS

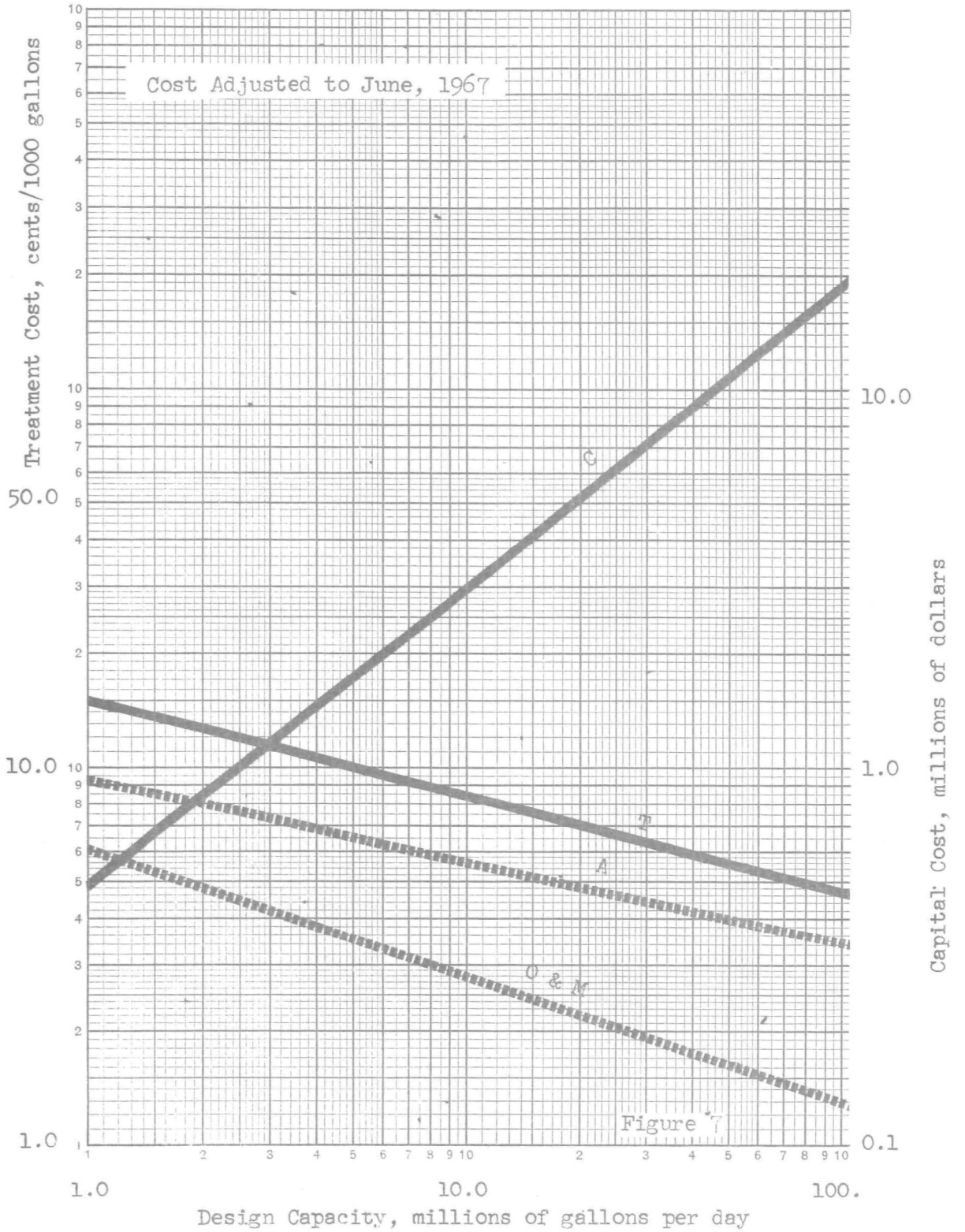
Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

TRICKLING FILTER PLANTS

Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

subject to various interpretations. For example, the amoritization period can be taken as the maturation period for the bonds. The amoritization period might also be taken as the maturation period for the plant or structure. This presents difficulties, however, because the useful life of equipment and structures varies sharply with the nature of the depreciating item. For example, a concrete tank might have a useful life of 40 years while equipment which moves or fouls such as sludge scrapers or aeration equipment might have a useful life of less than 20 years. To avoid this complexity, the amoritization period was taken as the maturation period of the bonds which was found to average about 25 years from data collected by the Division of Pollution Surveillance, FWPCA.

COAGULATION AND SEDIMENTATION

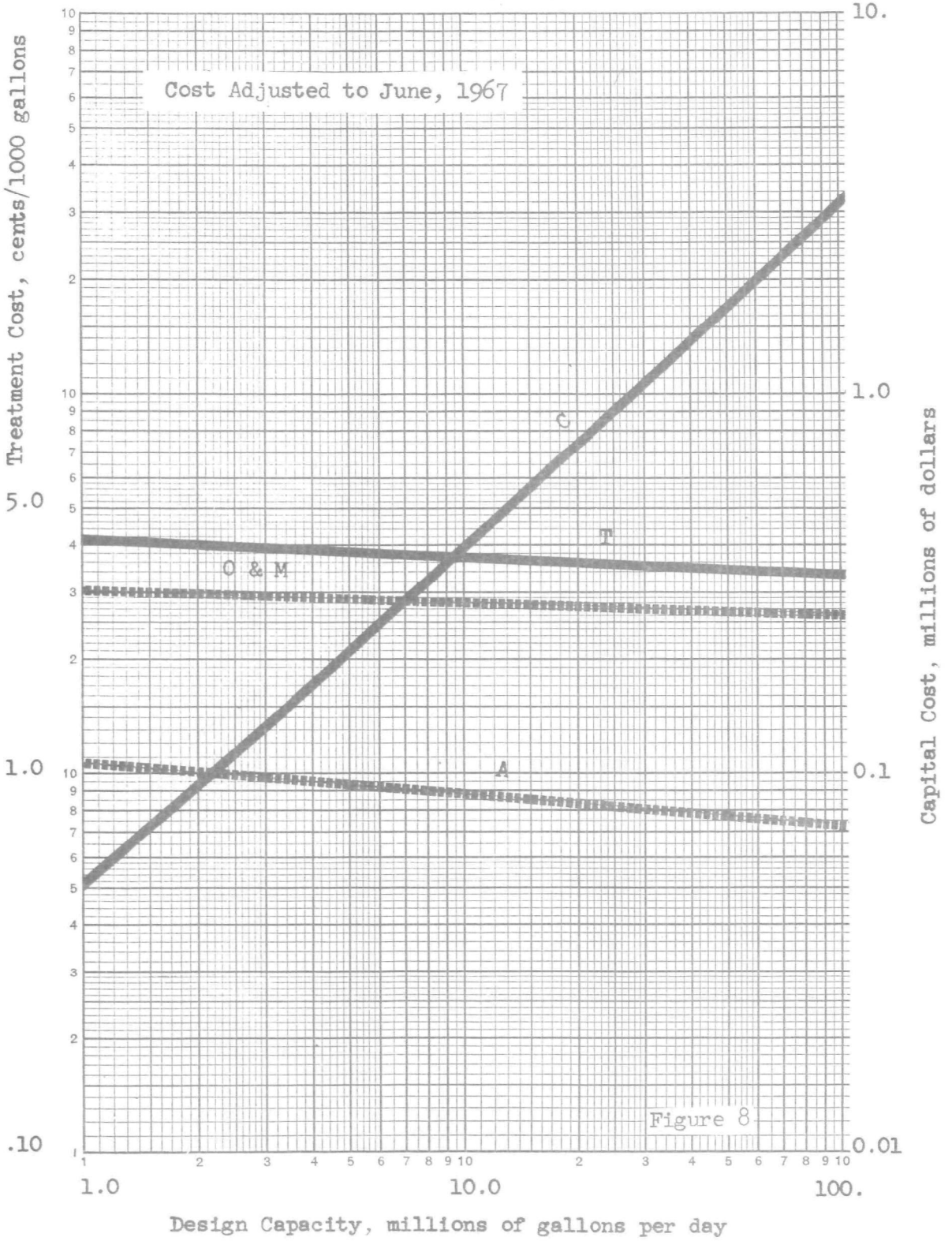
Cost estimates for coagulation and sedimentation after lime addition (Figure 8) were based primarily on references 10 and 11. Chemicals required were taken as 300 mg/l of hydrated lime and 50 mg/l of ferrous sulfate. The installed cost of Infilco Densators and associated chemical feeders are shown in Figure A-IV. Recovery of the settled lime by recalcination was assumed so that no lime disposal charges were incurred. The cost of purchasing lime in the Washington, D.C. area was found to be $18.50 per ton. Amoritization was based on retiring the loan in 25 years at 4 1/2% interest. If the settled sludge is to be disposed of by pipeline this cost can be estimated from Figure 17, and added to the values given in Figure 8.

FILTRATION THROUGH SAND OR GRADED MEDIA

The capital cost of sand filters operated at 4 gpm/sq. ft. (which is about twice the normal rate of 2 gpm/sq. ft. used in water purification plants) were taken from Orlob & Lindorf,[12] Koenig,[13] and Rehm & Plautz.[14] Operating and

SOLIDS REMOVAL BY COAGULATION & SEDIMENTATION

Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



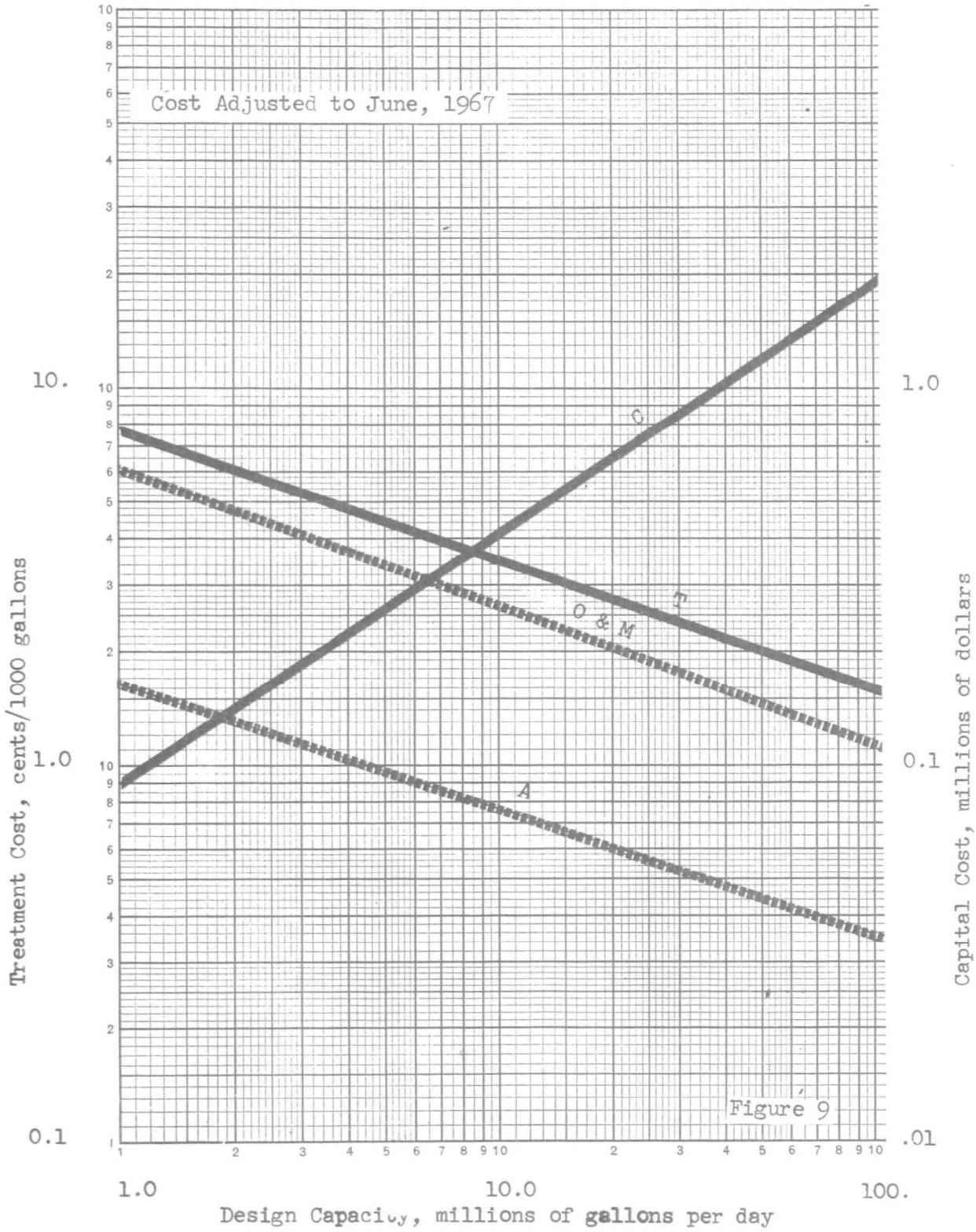
C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2 - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

FILTRATION THROUGH SAND OR GRADED MEDIA - 4GPM/SQ FT

Capital Cost, Operating & Maintenance Cost, Debt Service

vs.

Design Capacity



C = Capital Cost, millions of dollars

A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)

O & M = Operating and Maintenance Cost, cents per 1000 gallons

T = Total Treatment Cost, cents per 1000 gallons

maintenance cost was taken from the same three sources by subtracting the cost of chemicals. Amoritization charges were computed on the basis of retiring the bonds in 25 years at 4 1/2% interest.

AMMONIA STRIPPING

The capital cost of cooling towers for ammonia stripping was taken from Bauman[15] and the cost of power and operating and maintenance labor was taken from Smith and Chapman.[16] Amoritization charges were based on 25 years and 4 1/2% interest. It should be noted that the removal of ammonia by this process is strongly dependent on ambient temperature ranging from greater than 95% removal in the summer to a lower limit of 50-60% removal when the temperature is below zero degrees Centigrade.

GRANULAR CARBON ADSORPTION PROCESS

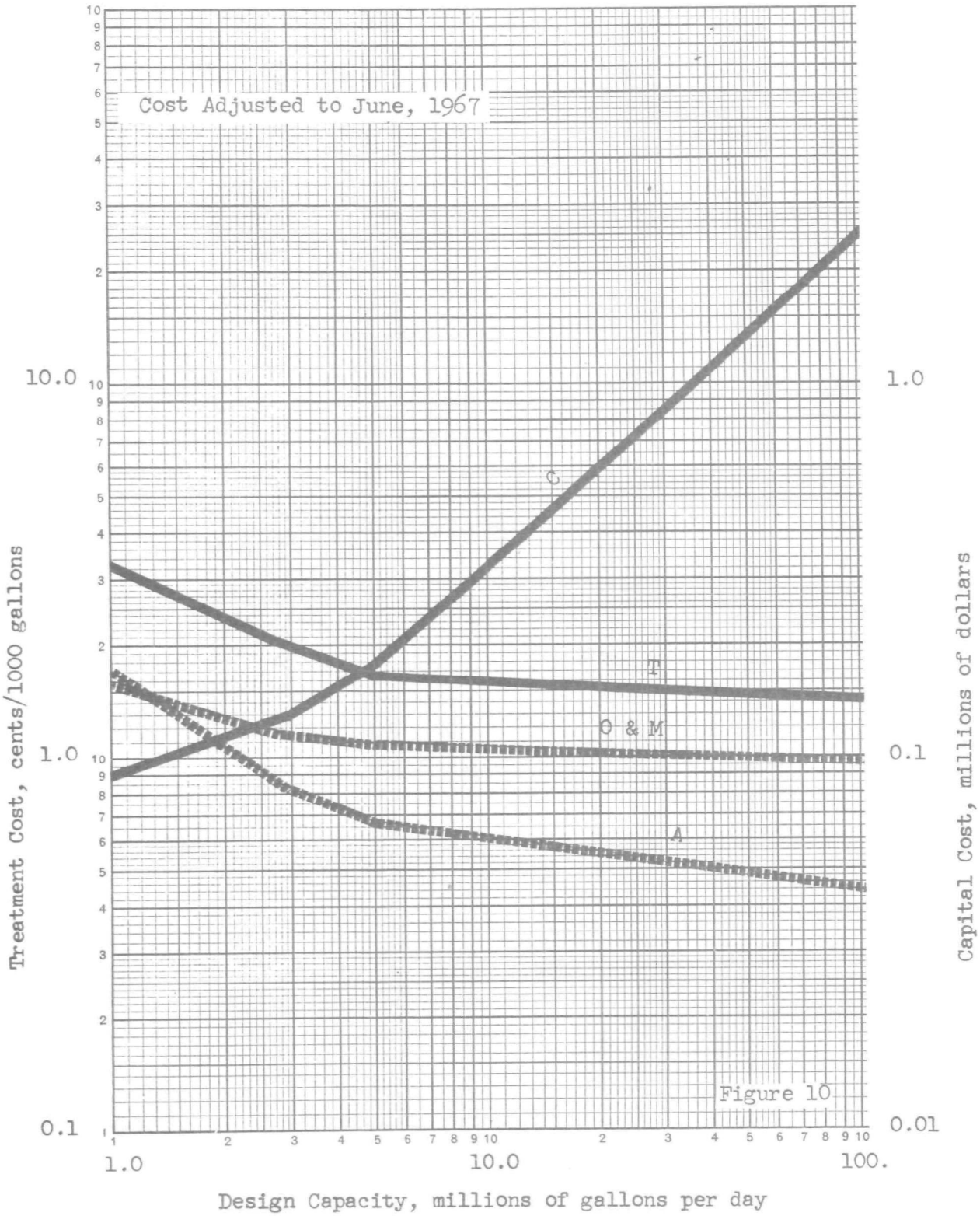
All cost data for the granular carbon adsorption process were taken from reference no. 17. The loss of carbon as a result of regeneration was taken as 7 1/2%. Amoritization charges were based on 25 years at 4 1/2% interest.

ELECTRODIALYSIS

Cost data for electrodialysis was taken from Ionics Inc. Publication No. 72[18] and a paper recently published by C.A. Brunner.[19] Amoritization charges were based on 25 years and 4 1/2% interest and no cost for brine disposal was included. The cost of brine disposal will depend on the location of the plant and the disposal means available. Cost estimates for disposal by pipelines are shown in Figure 17. Normally the brine stream is about 10% of the influent stream.

AMMONIA STRIPPING PROCESS

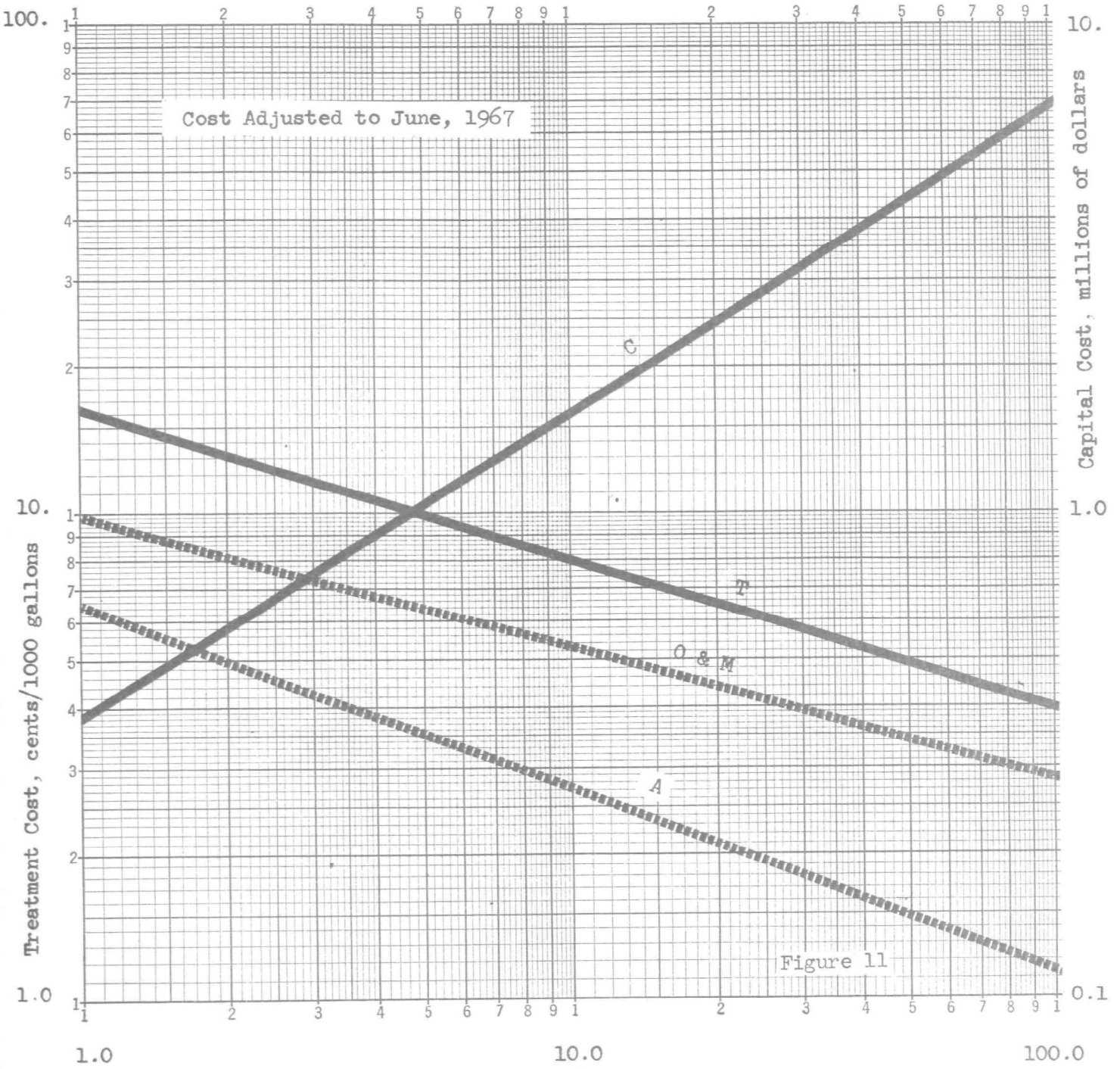
Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

GRANULAR CARBON ADSORPTION PROCESS

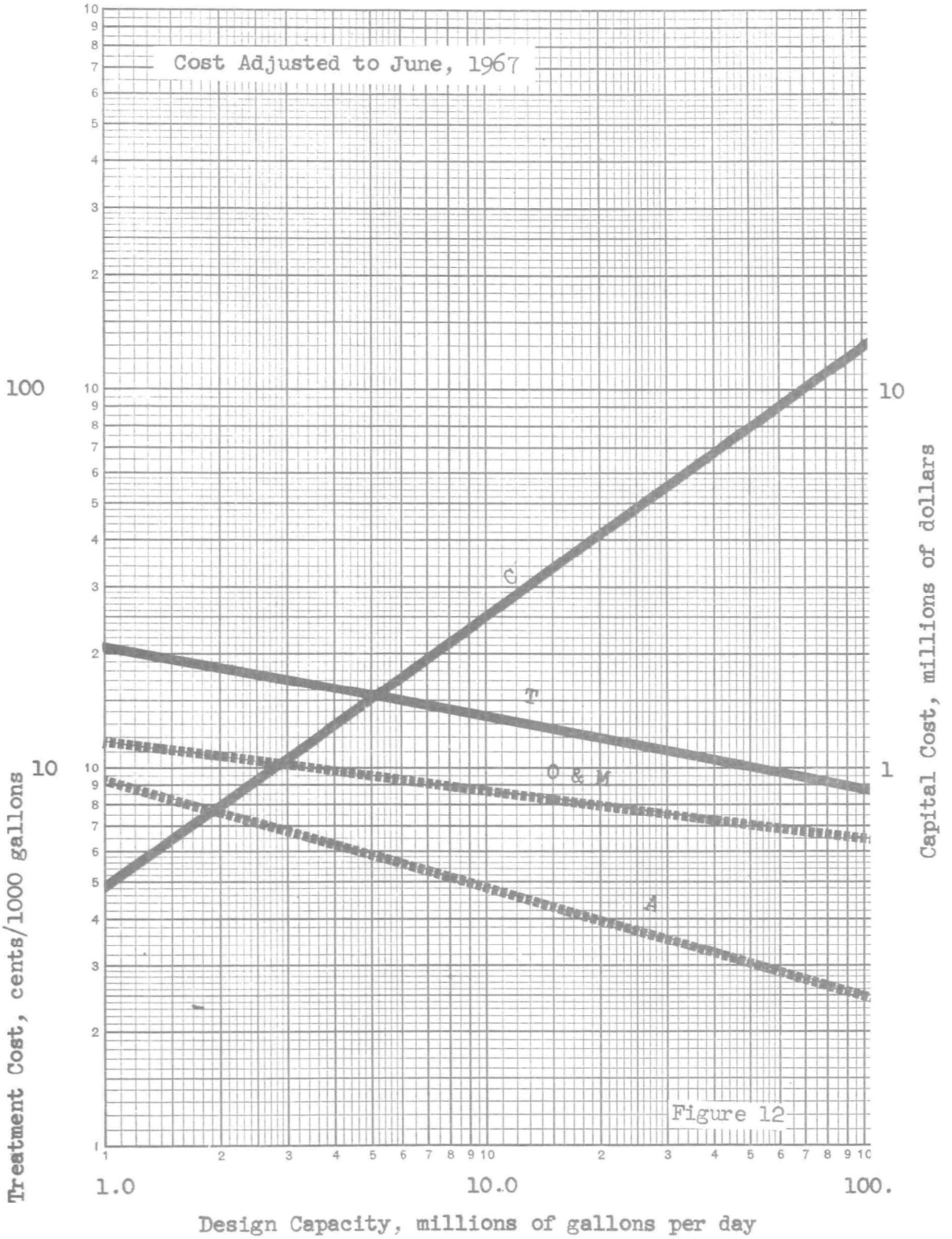
Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

ELECTRODIALYSIS

Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



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O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

MICROSTRAINING OF SECONDARY EFFLUENT

The cost of microstraining was taken from an estimate made by Bodien[20] for a 10 mgd plant receiving secondary effluent similar to that found at the Lebanon, Ohio Sewage Treatment Plant (27 mg/l suspended solids). A filterability index of 17 and a Mark I screen was used as the design basis. The slope of the capital line was arbitrarily taken as 9/10. The microstrainer, which operates with a head which varies from zero to six inches of water is easily overloaded as a result of high suspended solids in the influent stream. The quality of the effluent from the microstrainer also varies with the concentration of suspended solid of the feed and the nature of the solids. Adequate design procedures for sizing Microstrainers for use on secondary effluent are needed.

AERATION OF SECONDARY EFFLUENT

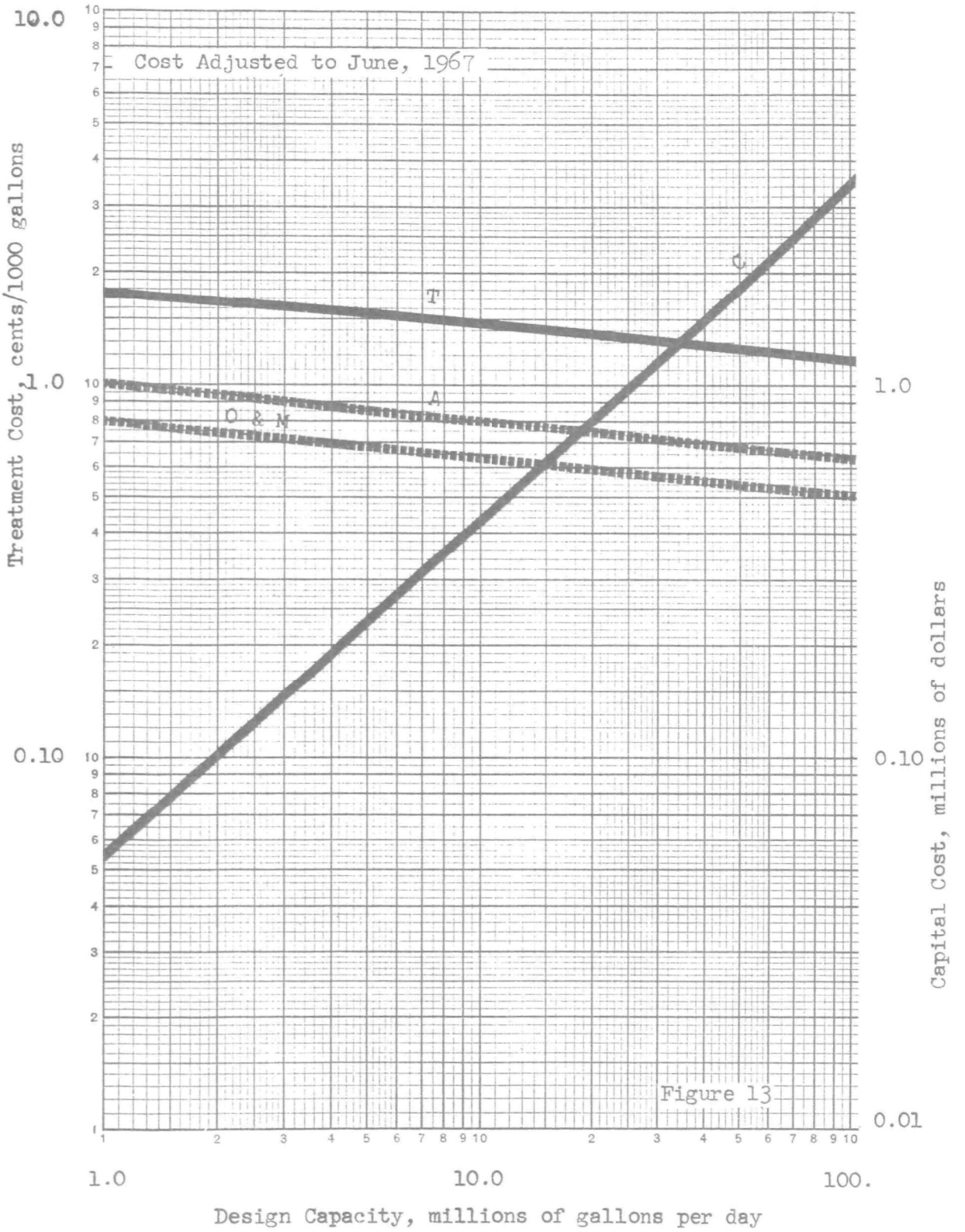
Cost estimates by Roesler and Smith[21] are based on building an aeration tank downstream of an activated sludge plant. The tank was assumed to be concrete with typical aeration equipment. Additional blowers were provided to supply the air needed. Electrical power was assumed to cost one cent per kilowatt hour. The costs shown in Figures 14 and 15 are for water at 20°C. If the temperature is increased to 30°C the cost estimates shown in Figures 14 and 15 should be multiplied by a factor of about two.

CHLORINATION OF SECONDARY EFFLUENT

The design basis of 15 minutes contact time and 8 mg/l of chlorine recommended by the Ten State Standards[22] was used in making this cost estimate. The cost of chlorine was taken as 8.0 cents per pound.

MICROSTRAINING OF SECONDARY EFFLUENT

Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



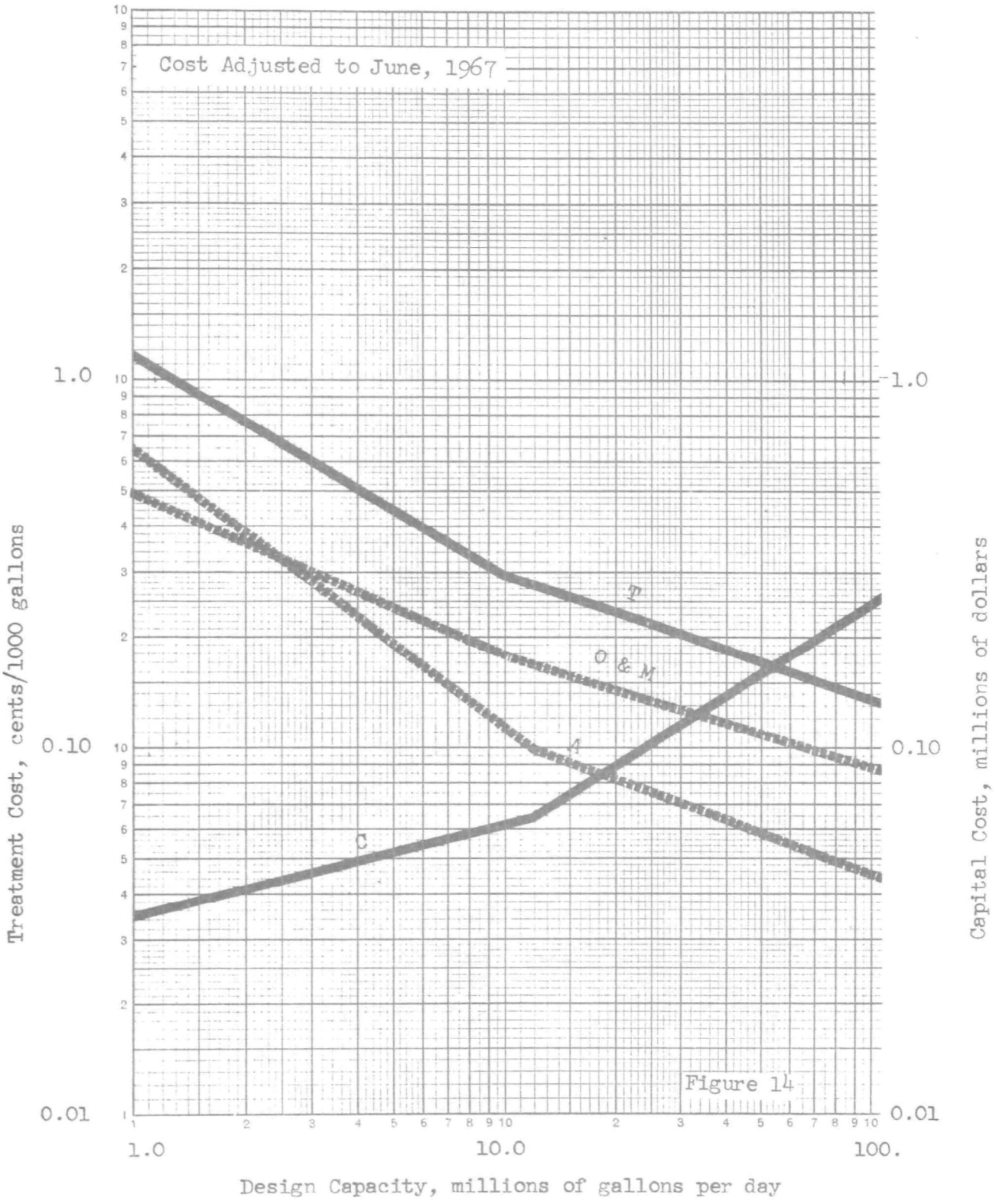
C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

AERATION OF SECONDARY EFFLUENT TO RAISE D.O. FROM 1.0 mg/l to 4.0 mg/l

Capital Cost, Operating & Maintenance Cost, Debt Service

vs.

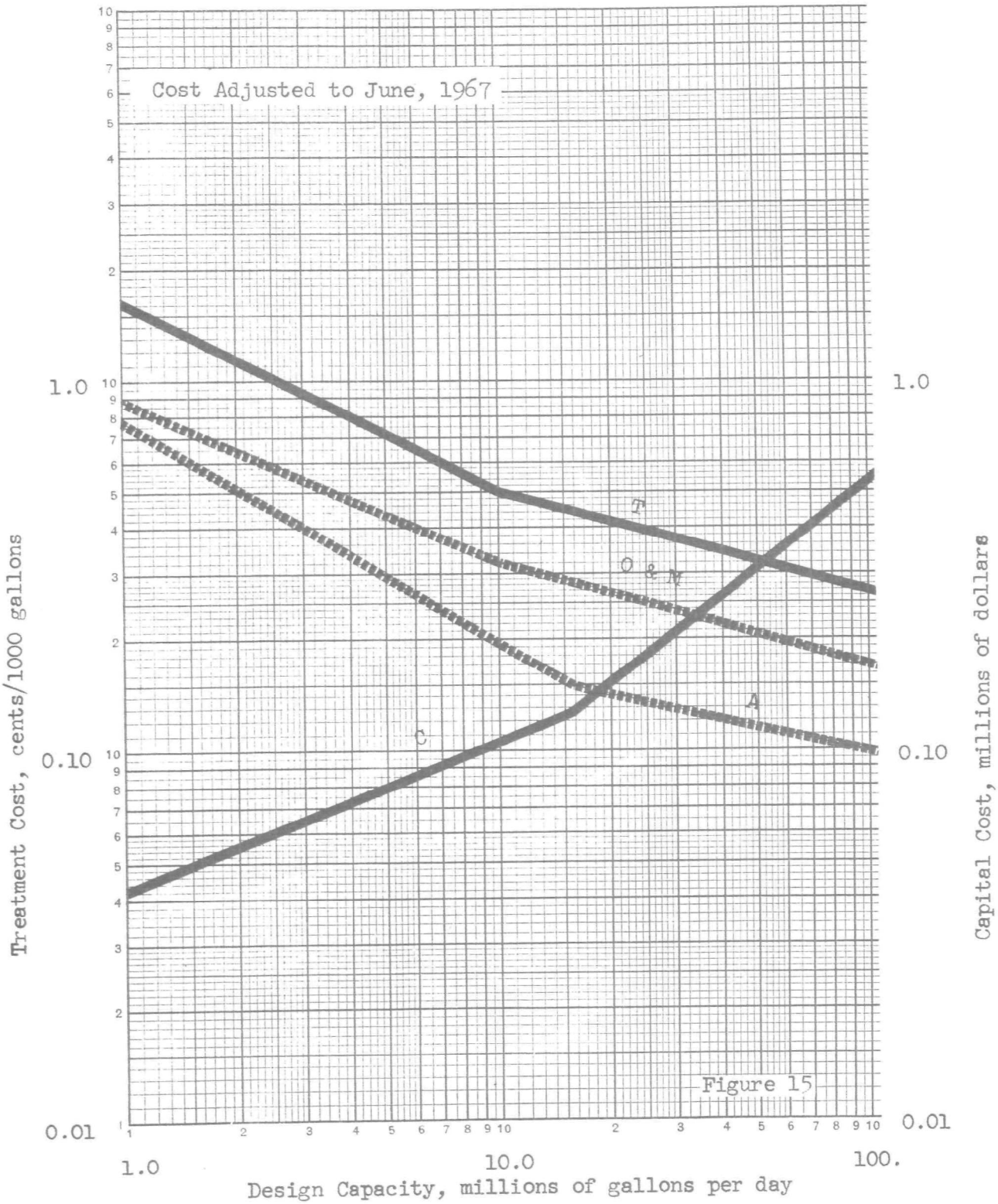
Design Capacity



C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

AERATION OF SECONDARY EFFLUENT TO RAISE D.O. FROM 1.0 mg/l to 6.0 mg/l

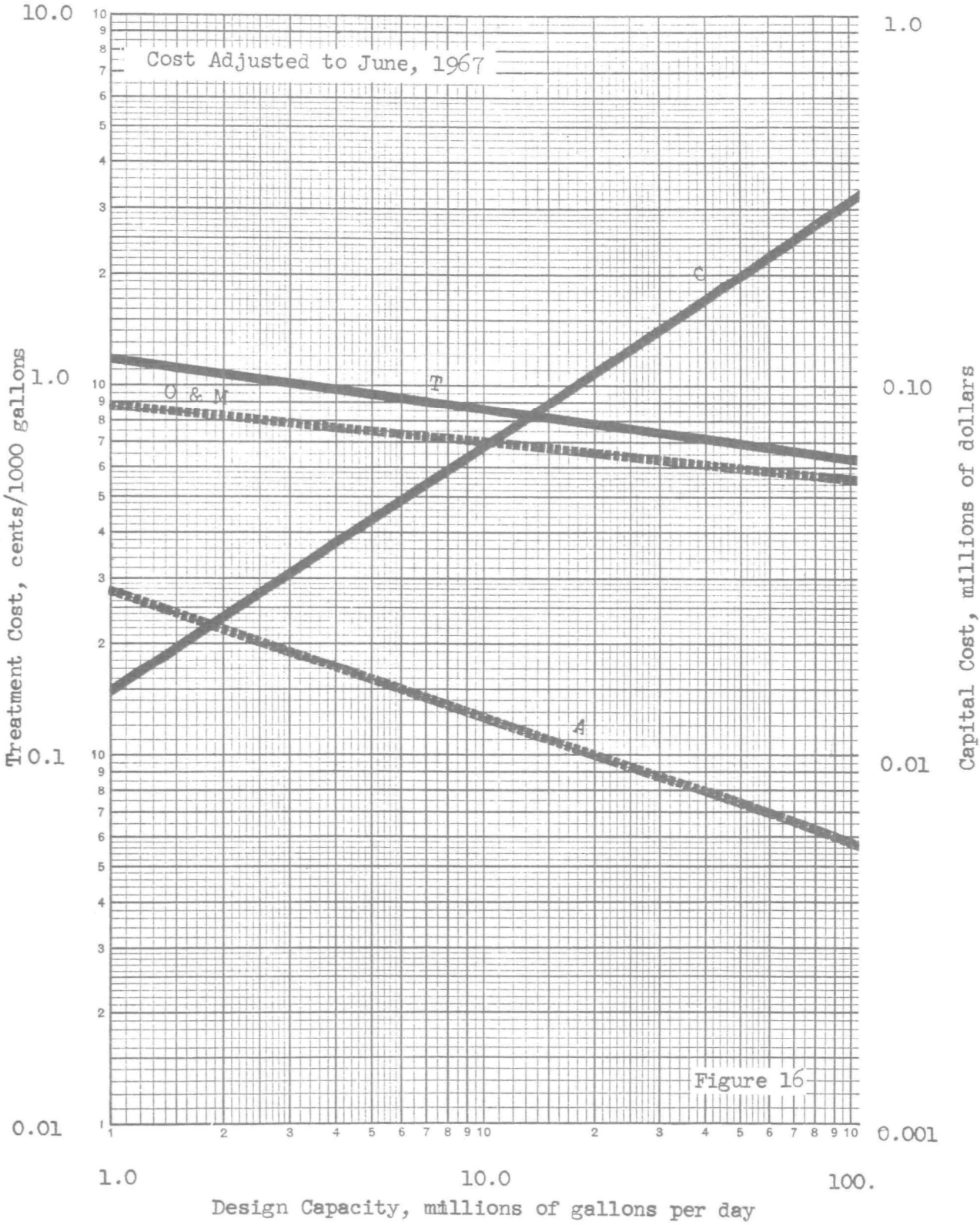
Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

CHLORINATION OF SECONDARY EFFLUENT

Capital Cost, Operating & Maintenance Cost, Debt Service
vs.
Design Capacity



C = Capital Cost, millions of dollars
A = Debt Service, cents per 1000 gallons(4 1/2% - 25 yr.)
O & M = Operating and Maintenance Cost, cents per 1000 gallons
T = Total Treatment Cost, cents per 1000 gallons

PIPELINES FOR ULTIMATE DISPOSAL

The cost of building and operating pipelines as shown in Figure 17 was computed from relationships given in the Office of Saline Water R&D Report No. 257.[23] The capital cost includes the construction cost of the pipe and the capital cost of pumping stations. It was assumed that one pumping station would be installed for each 400 ft. of dynamic head. Only frictional drop was considered and this was taken as eight feet of water per mile for pipe sizes greater than 1.0 mgd and 20 feet of water per mile for the 0.1 mgd size. Operating and maintenance cost was taken as 0.25% per year of the total capital cost. In most cases, however, the major part of the total cost was amoritization charges which were computed on a 30 yr. - 3 1/4% interest basis. The cost of electrical power was assumed to be one cent per kilowatt hour.

CAPITAL COST OF INDIVIDUAL EQUIPMENT, STRUCTURES, AND CONSUMABLE ITEMS

Most of the cost estimates for individual components of conventional wastewater treatment plants now available were developed by George S. Russell[1] working in collaboration with Lynn, Hatfield, and Logan at Northwestern University under a research grant from the Public Health Service. The original cost estimates were obtained from Dr. W.R. Lynn, now at Cornell University, and plotted versus the most significant design parameter. For example, the cost of settling tanks was plotted versus overflow area and the cost of aerators was plotted versus the volume of the aerator. These plots are shown in Figures 18-28.

From the work of Russell the capital cost of heating equipment for the digester was found to be represented by the following relationship:

$$\text{Capital Cost, dollars} = \$5000 + \$40(\text{Digester Volume, cu. ft./1000})$$

The cost of constructing sludge drying beds was found to be $2.23 per sq. ft. The cost of improvements in the plant site can be represented by the following equation:

COST OF PIPELINES FOR ULTIMATE DISPOSAL

Capital Cost & Total Cost versus Design Capacity

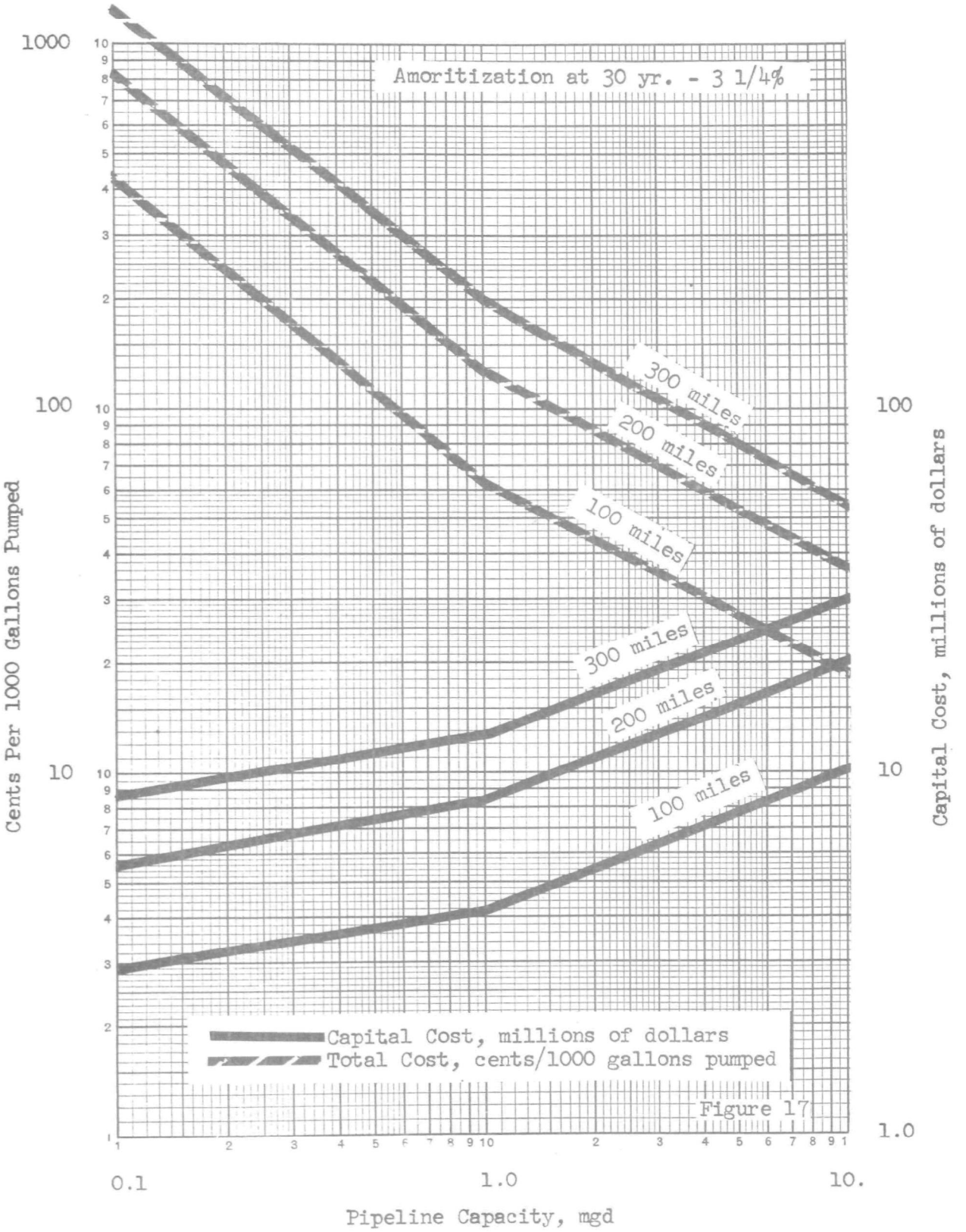
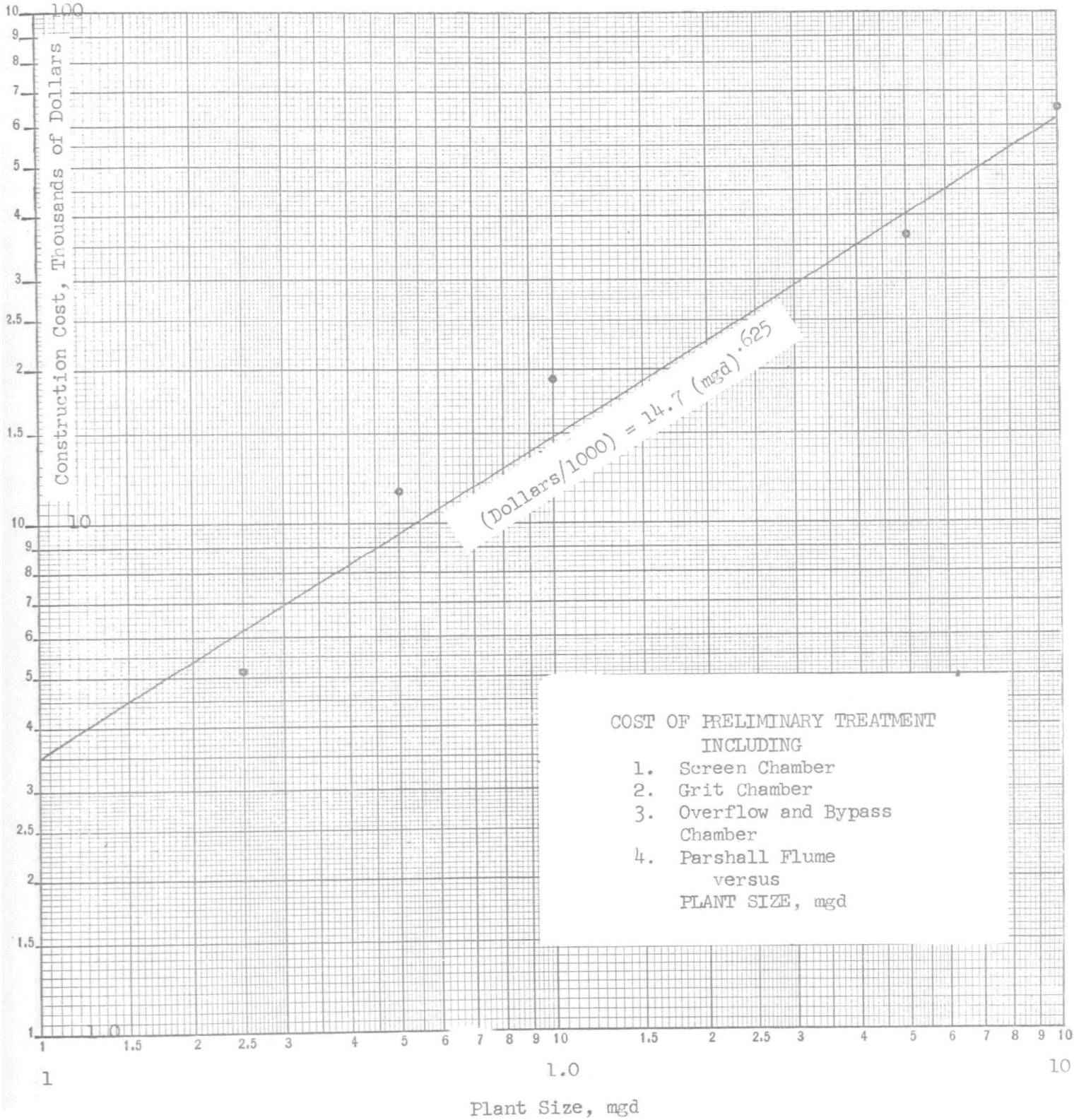


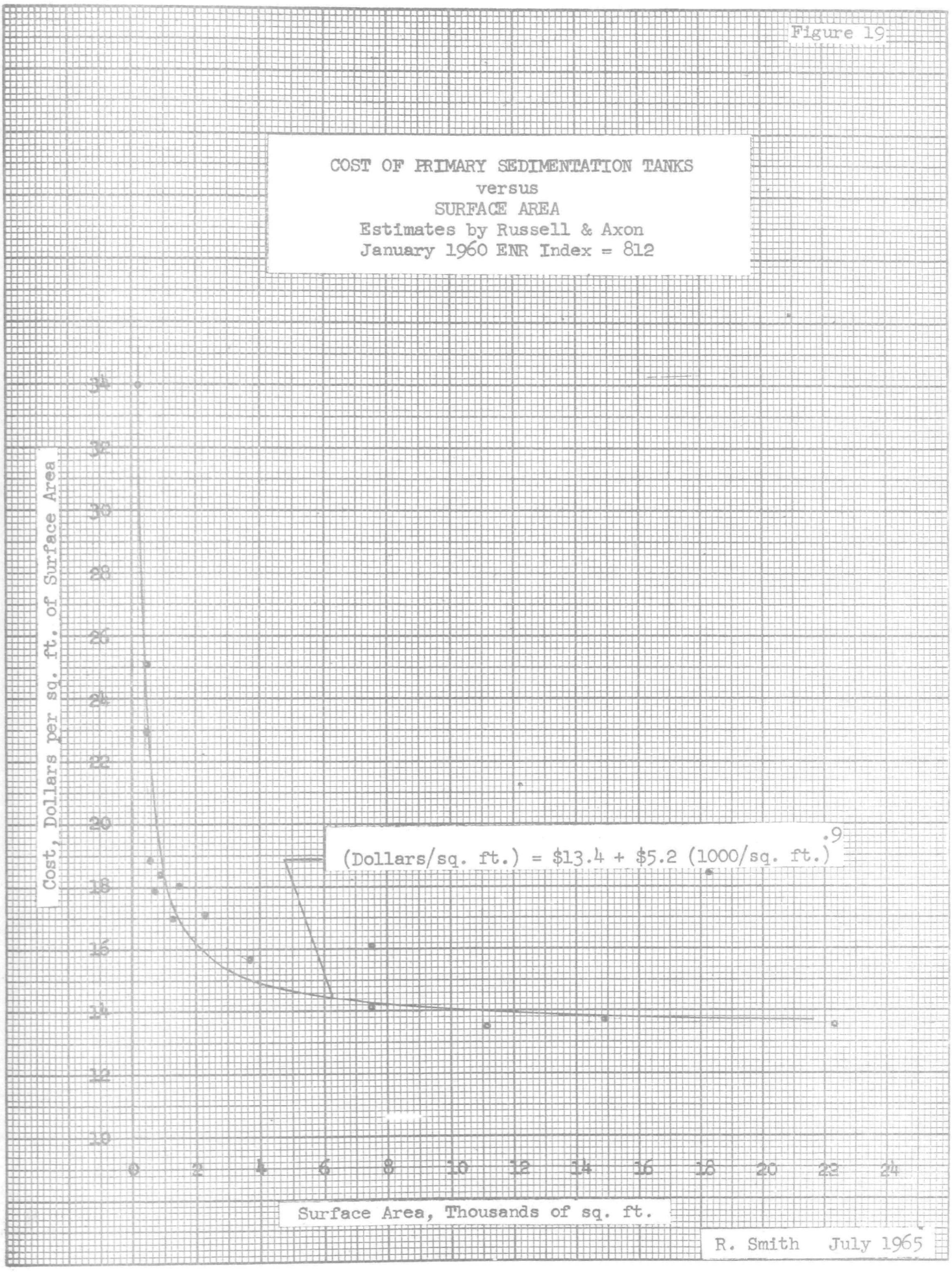
Figure 17

Figure 18



R. Smith July 1965

Figure 19


COST OF PRIMARY SEDIMENTATION TANKS
versus
SURFACE AREA
Estimates by Russell & Axon
January 1960 ENR Index = 812
Cost, Dollars per sq. ft. of Surface Area
34
32
30
28
26
24
22
20
18
16
14
12
10
0
2
4
6
8
10
12
14
16
18
20
22
24
(Dollars/sq. ft.) = $13.4 + $5.2 (1000/sq. ft.)^.9
Surface Area, Thousands of sq. ft.
R. Smith July 1965

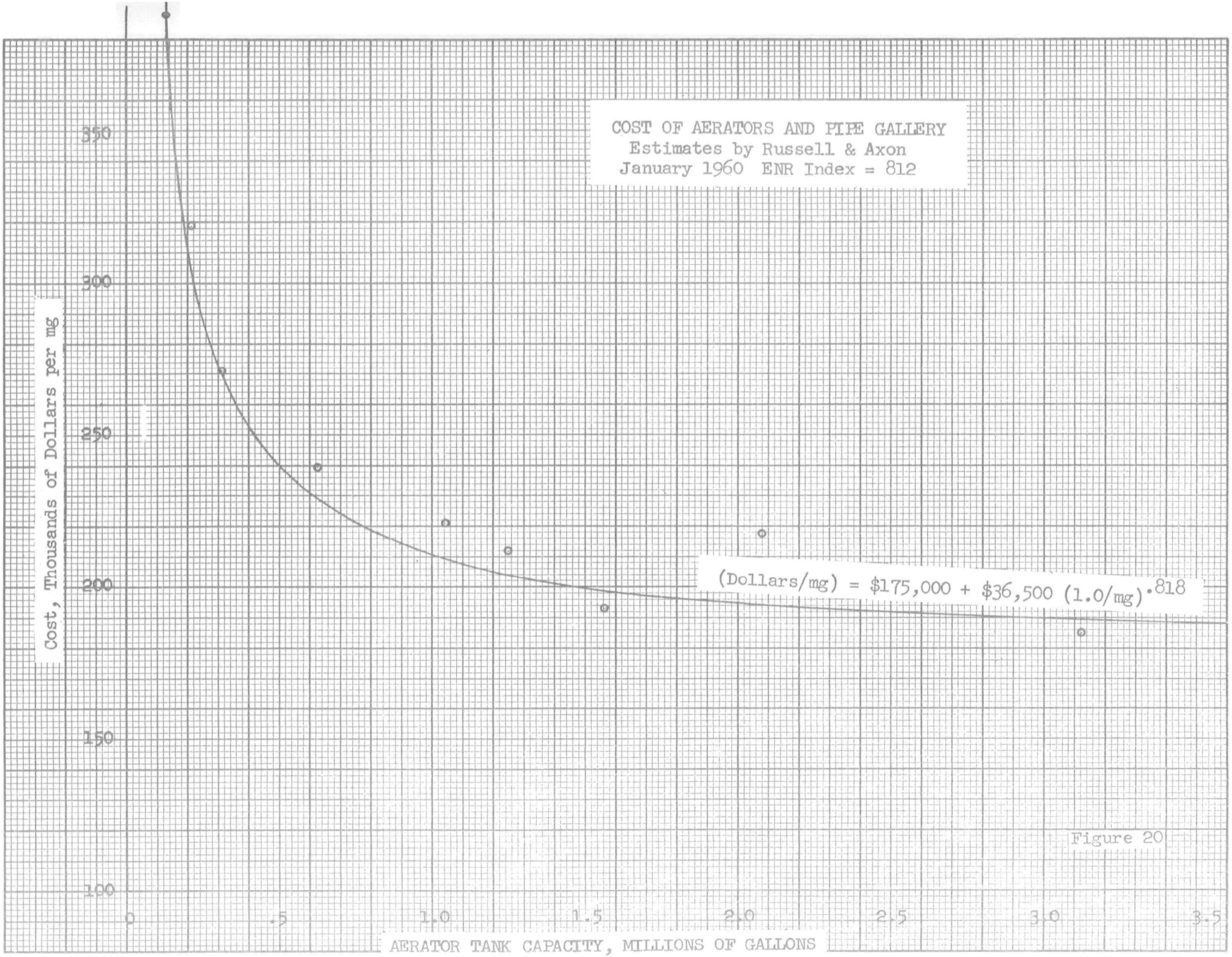
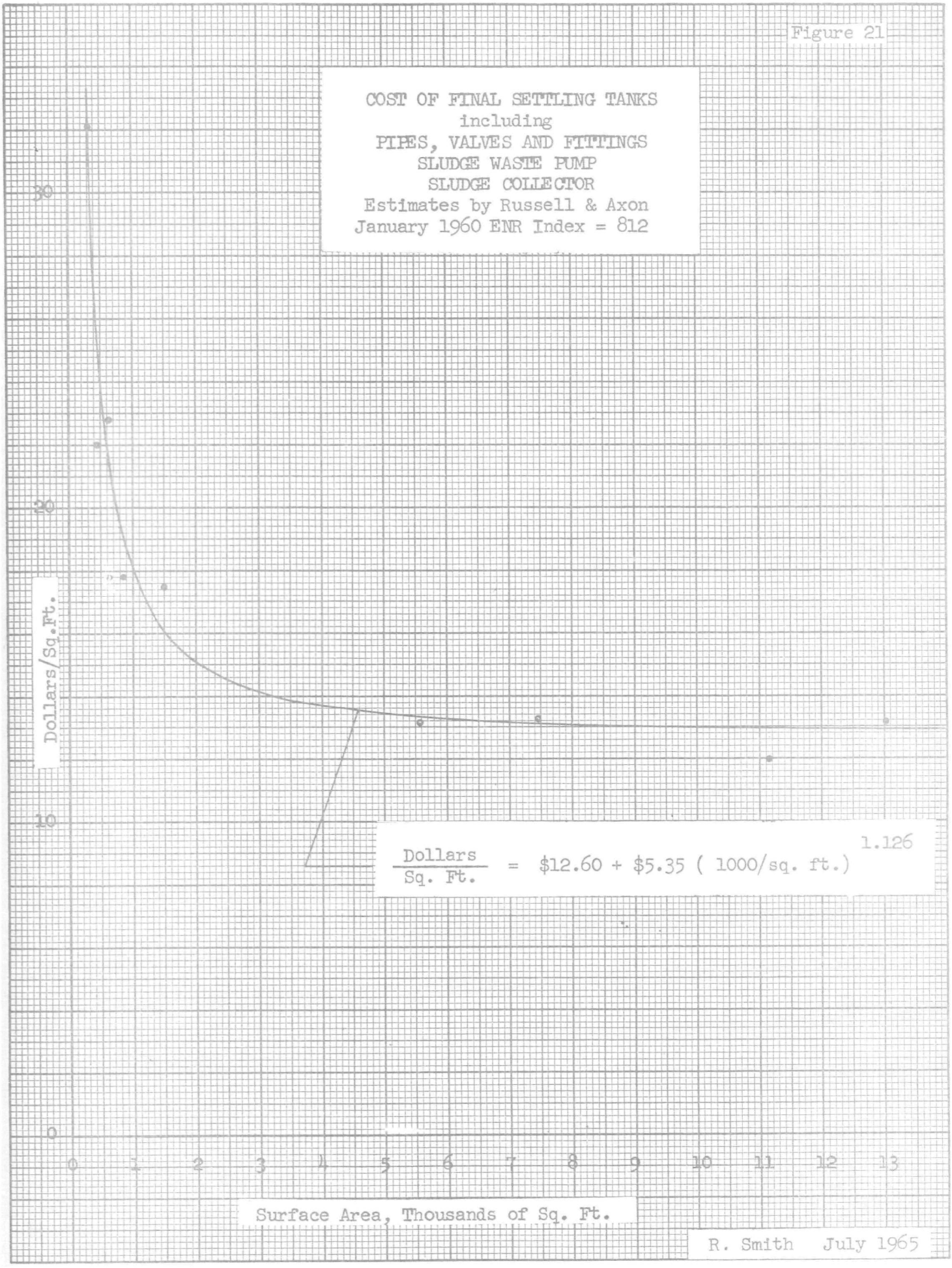

COST OF AERATORS AND PIPE GALLERY
Estimates by Russell & Axon
January 1960 ENR Index = 812
(Dollars/mg) = $175,000 + $36,500 (1.0/mg)^.818
Cost, Thousands of Dollars per mg
350
300
250
200
150
100
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
AERATOR TANK CAPACITY, MILLIONS OF GALLONS

Figure 20

Figure 21


COST OF FINAL SETTLING TANKS
including
PIPES, VALVES AND FITTINGS
SLUDGE WASTE PUMP
SLUDGE COLLECTOR
Estimates by Russell & Axon
January 1960 ENR Index = 812
Dollars/Sq.Ft.
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Surface Area, Thousands of Sq. Ft.
Dollars / Sq. Ft. = $12.60 + $5.35 (1000/sq. ft.)^1.126
R. Smith July 1965

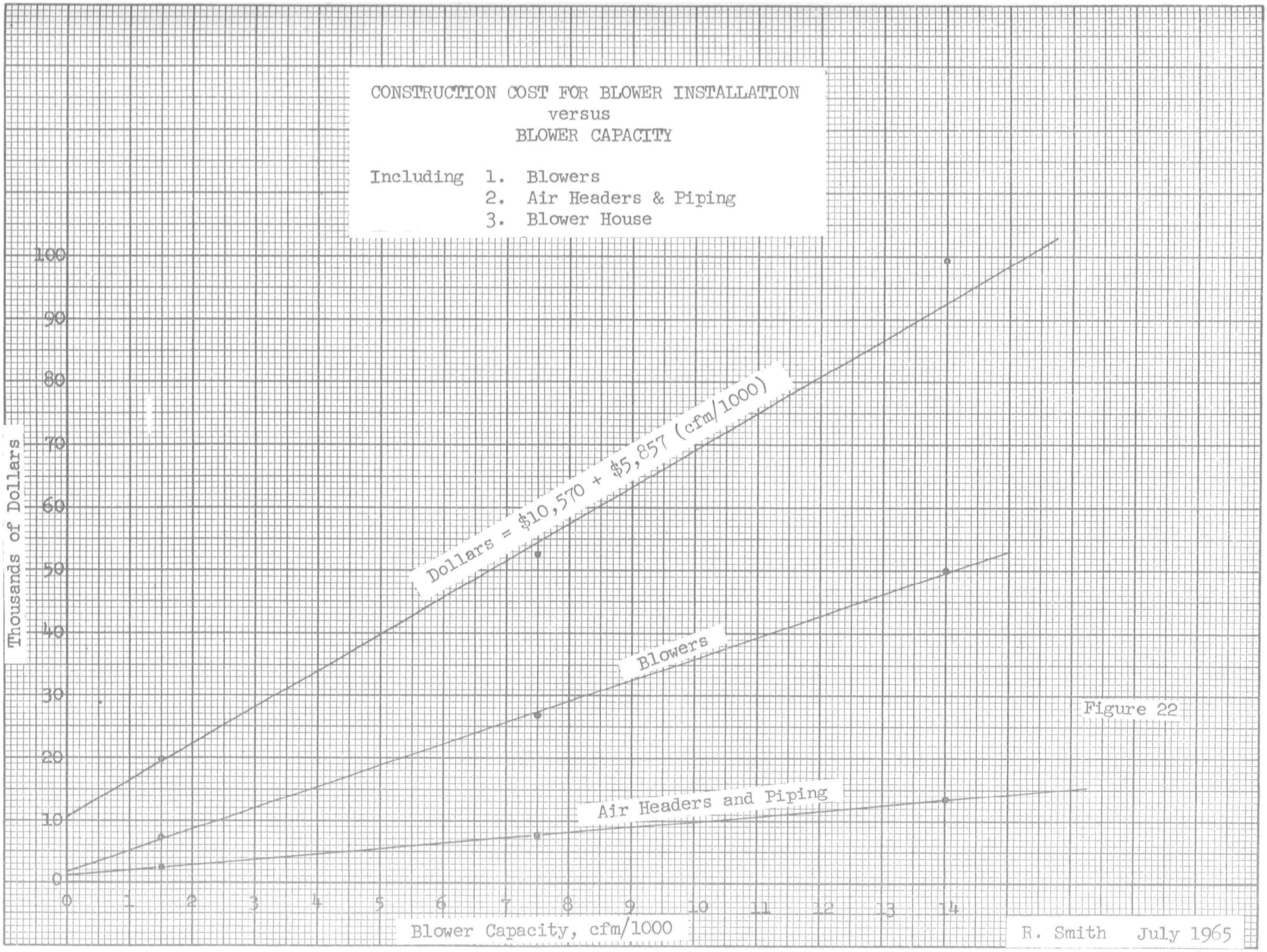
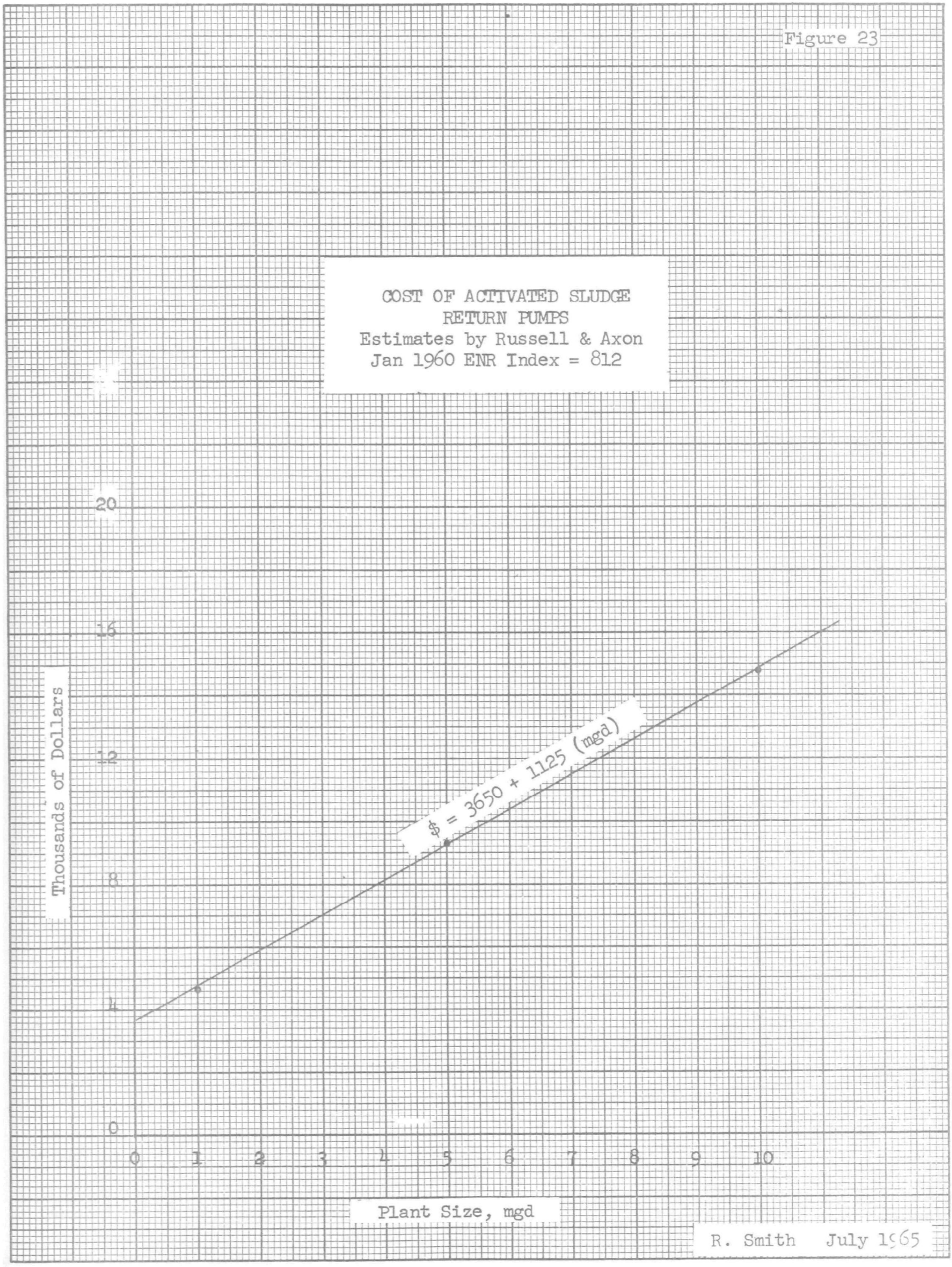

CONSTRUCTION COST FOR BLOWER INSTALLATION
versus
BLOWER CAPACITY
Including 1. Blowers
2. Air Headers & Piping
3. Blower House
Dollars = $10,570 + $5,857 (cfm/1000)
Blowers
Air Headers and Piping
Thousands of Dollars
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Blower Capacity, cfm/1000
R. Smith July 1965

Figure 22

Figure 23


COST OF ACTIVATED SLUDGE
RETURN PUMPS
Estimates by Russell & Axon
Jan 1960 ENR Index = 812
Thousands of Dollars
20
16
12
8
4
0
$ = 3650 + 1125 (mgd)
0
1
2
3
4
5
6
7
8
9
10
Plant Size, mgd
R. Smith July 1965

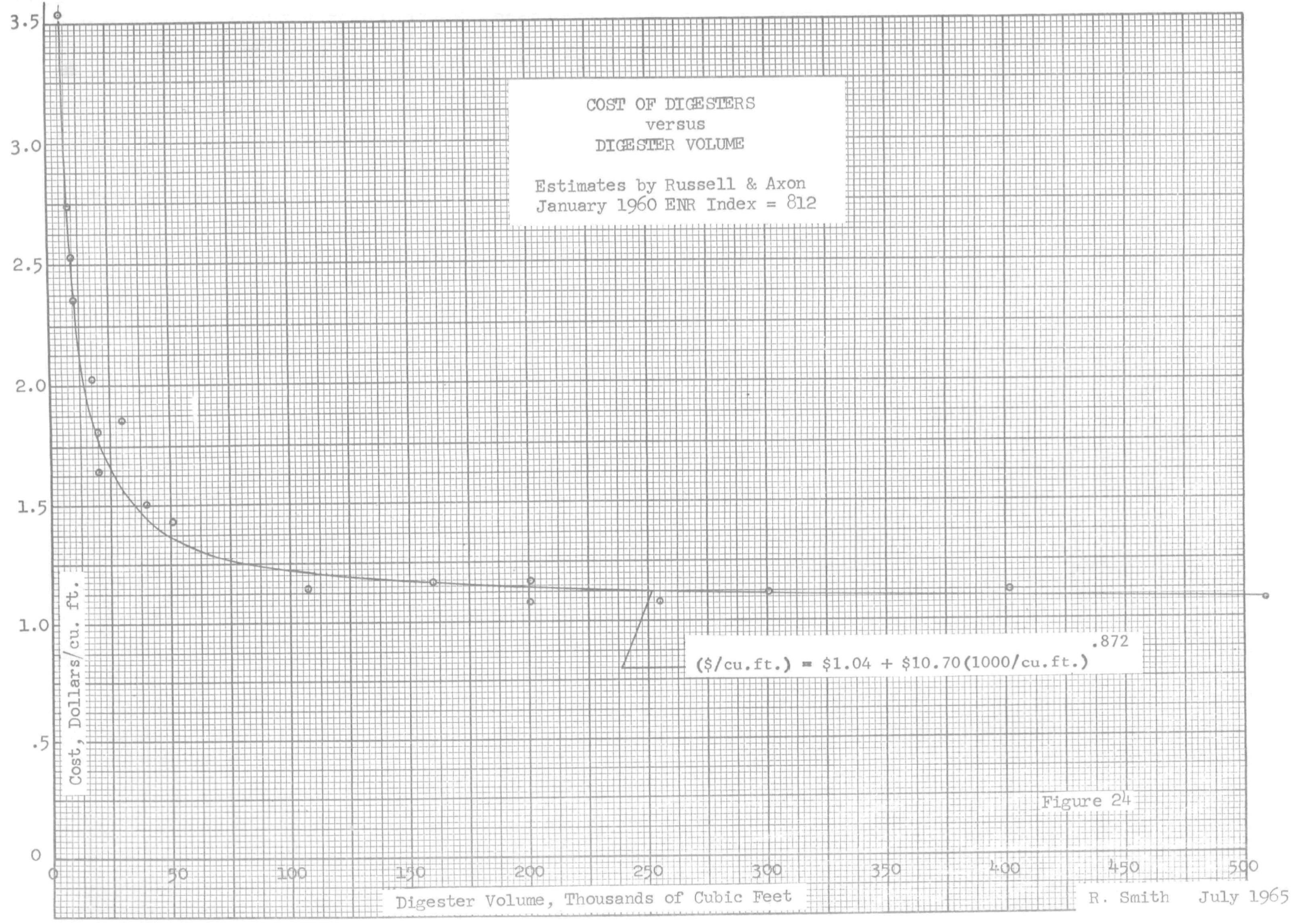


Figure 24

R. Smith July 1965

Figure 25

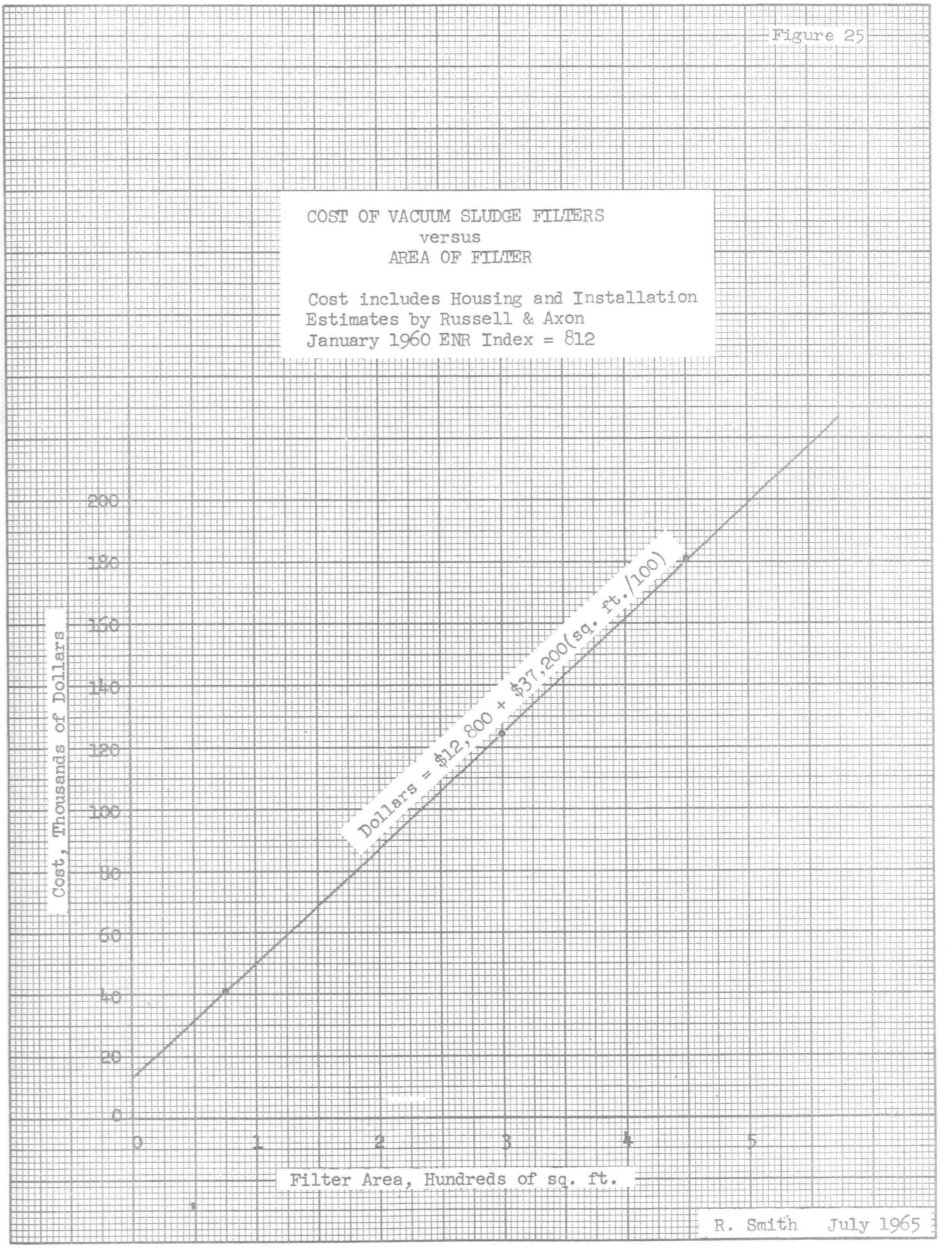
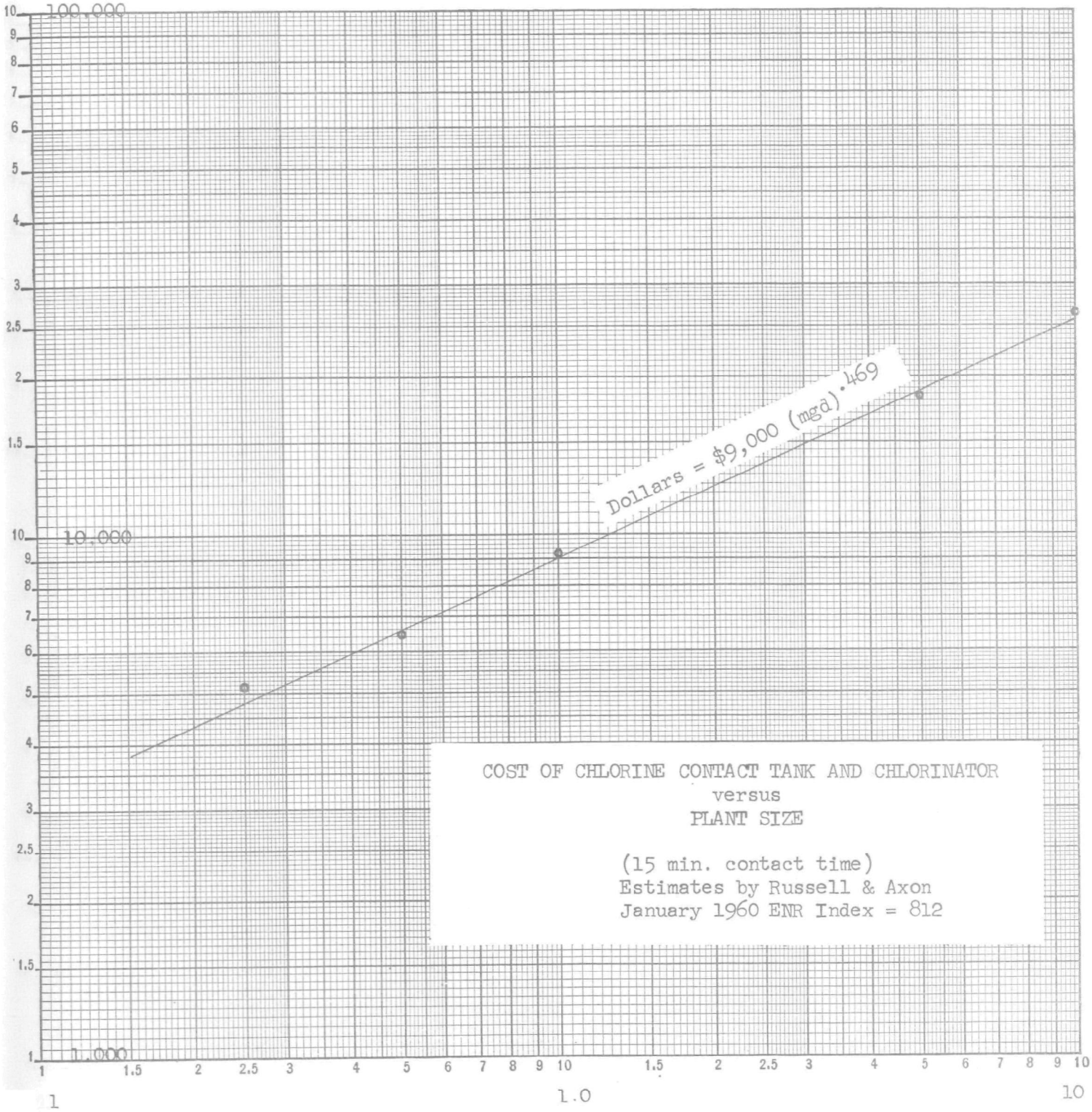
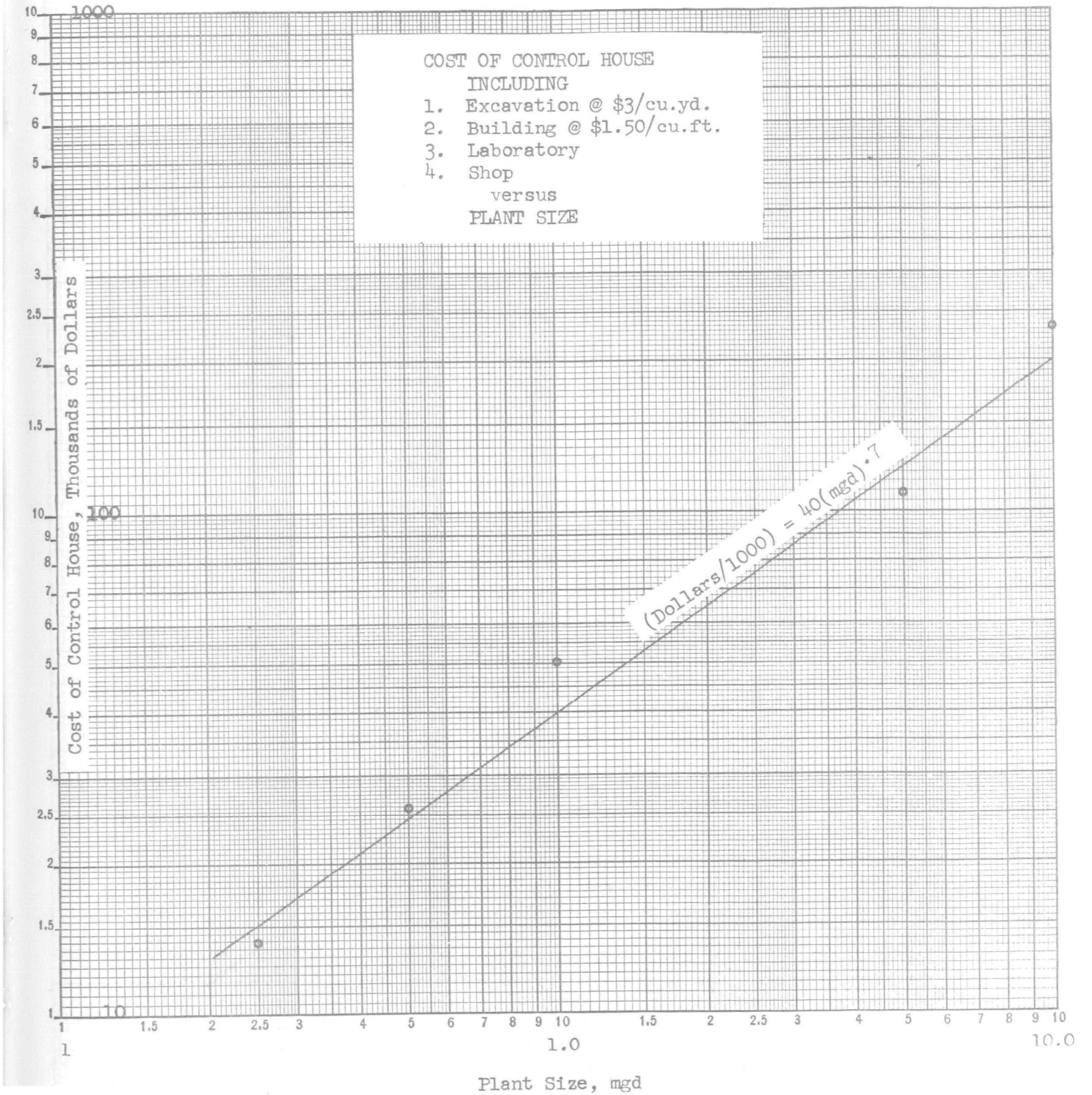

COST OF VACUUM SLUDGE FILTERS
versus
AREA OF FILTER
Cost includes Housing and Installation
Estimates by Russell & Axon
January 1960 ENR Index = 812
Dollars = $12,800 + $37,200(sq. ft./100)
Cost, Thousands of Dollars
0
20
40
60
80
100
120
140
160
180
200
0
1
2
3
4
5
Filter Area, Hundreds of sq. ft.
R. Smith July 1965

Figure 26



R. Smith July 1965

Figure 27

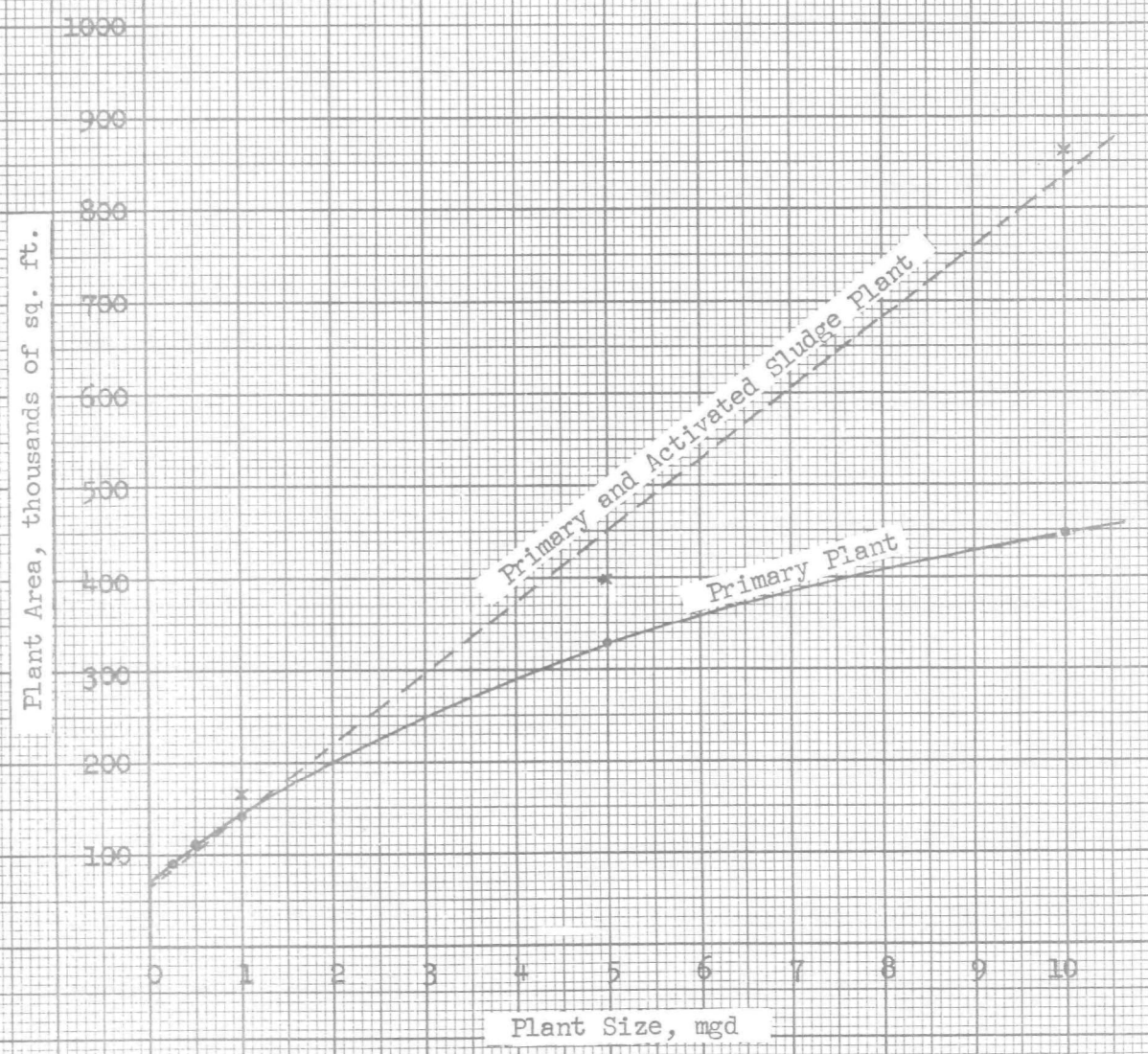


R. Smith July 1965

Figure 28

LAND REQUIREMENTS FOR PRIMARY AND
PRIMARY WITH ACTIVATED SLUDGE PLANTS
versus
PLANT SIZE

Estimates by Russell & Axon



R. Smith July 1965

$$\text{Capital Cost, dollars} = \$4400(\text{mgd})^{0.875}$$

Construction cost for sludge thickeners and elutriation tanks were taken from the personal file of Mr. C. Swanson of FWPCA. These are shown below where ATHM is the surface area of the thickener in sq. ft. and AE is the surface area of the sludge elutriation tanks in sq. ft.

UNIT PROCESS	CAPITAL COST, dollars
Sludge Thickeners	(18.8 + 9.1/exp(ATHM/13,300))ATHM
Sludge Elutriation Tanks	(18.8 + 52.0/exp(AE/6000))AE

All cost estimates supplied by Russell and Swanson are keyed to prices in St. Louis, Mo. in January, 1960. This corresponds to a value of 105.23 for the PHS Sewage Treatment Construction Cost Index. Since the PHS index was 119.11 for June, 1967 these cost estimates should be multiplied by 1.13 to adjust them to the national average level for June, 1967. The cost of influent pumps was obtained from a manufacturer and applies to May, 1965.

In using these data to synthesize the total cost of complete plants it was found that the following additional costs expressed as a percentage of the total construction cost were necessary to make the synthesized cost for the complete plant agree with reported values from operating plants.

1. Contractor's Profit----------10%
2. Contingencies and Omissions----------15%
3. Land Acquisition 2%
4. Engineering---------- 6-12%

Representative engineering costs as a function of the total construction cost is shown in Tables A-VI and A-VII and Figures A-II and A-III.

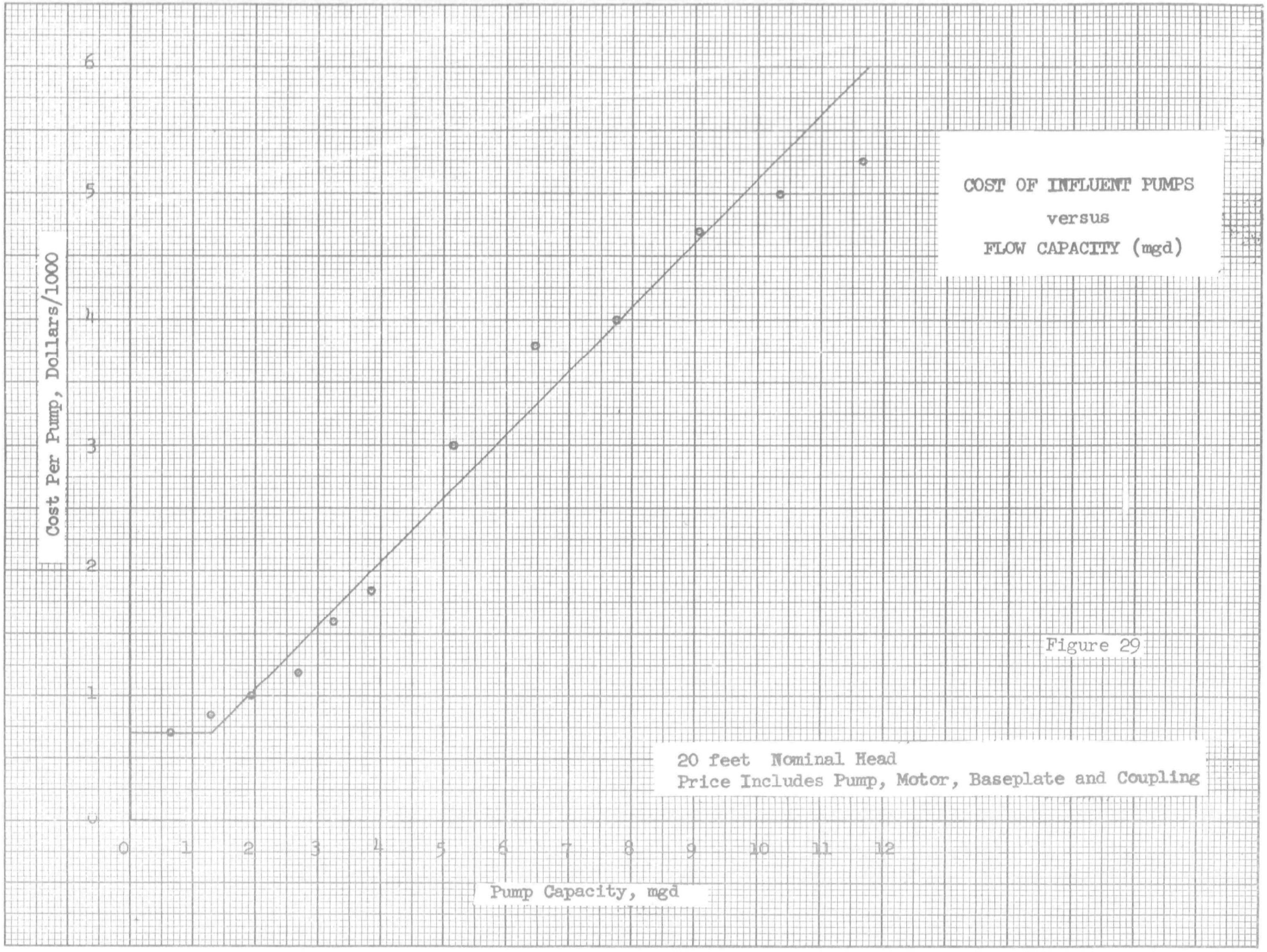

COST OF INFLUENT PUMPS
versus
FLOW CAPACITY (mgd)
Cost Per Pump, Dollars/1000
0
1
2
3
4
5
6
0
1
2
3
4
5
6
7
8
9
10
11
12
Pump Capacity, mgd
20 feet Nominal Head
Price Includes Pump, Motor, Baseplate and Coupling

Figure 29

It was also found that if the equipment and structures are sized on the reported average performance of the processes; extra capacity must be provided for cleaning and maintenance. Extra capacity can be provided by multiplying the computed average size required by an Excess Capacity Factor. The values used for Excess Capacity Factors will depend on the specific design problem, but average representative values are given in the following list:

UNIT PROCESS	EXCESS CAPACITY FACTOR
Preliminary Treatment	1.0
Primary Settling	2.0
Aerator	1.2
Air Blowers	1.5
Final Settler	2.0
Sludge Return Pumps	2.0
Control House	1.0
Thickener	1.5
Digesters	2.0
Sludge Elutriation	1.5
Vacuum Filter	1.0
Incinerator	1.0
Sludge Drying Beds	1.0
Chlorination	1.0
Plant Site Preparation	1.0

The cost of hauling by truck in Cincinnati was found to vary from 16 cents per ton-mile for a two mile one-way trip to 3.5 cents per ton-mile for a 45 mile one-way trip. The cost of barging sludge to sea was found to be $3.50 per ton for a 225 one-way trip from the Washington, D.C. area or about 1.6 cents per ton-mile.

The following table supplied by Koenig[13] shows the average price paid for chemicals in water plants:

Distribution of Unit Prices	No. of Points	Dist'n Type	Value of Factor at 10%	50%	90%	σ ratio
Superv. labor, large, dollars/hr	14	log	1.73	3.35	6.51	1.67
Superv. labor, small, dollars/hr	6	log	1.35	2.12	3.35	1.42
Op & Maint labor, large, dollars/hr	14	log	1.65	2.40	3.50	1.34
Op & Maint labor, small, dollars/hr	13	log	1.31	1.75	2.30	1.23
General labor, dollars/hr	9	log	1.04	1.58	2.40	1.39
Elec. energy, large, cents/KWH	14	log	.65	.92	1.30	1.32
Elec. energy, small, cents/KWH	11	log	.98	1.48	2.22	1.36
Oil, cents/gas/gal	5	log	9.8	12.	18.2	1.40
Alum, large, cents/lb	13	log	2.37	2.65	3.00	1.09
Alum, small, cents/lb	11	log	3.31	3.89	4.50	1.13
Alkali, large, cents/lb, h.l. equiv.	11	arith	.68	1.14	1.60	1.32
Alkali, small, cents/lb, h.l. equiv.	10	arith	.35	2.40	4.10	1.53
Chlorine, large, cents/lb	14	log	4.15	5.20	9.10	1.62
Chlorine, small, cents/lb	12	log	9.10	12.50	17.50	1.30
Carbon, cents/lb	10	arith	8.50	11.80	15.20	1.29

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11. Smith, R., "Status of Cost Information on Phosphate Removal," FWPCA Memo to Record (July 1, 1967).

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15. Bauman, H. Carl, "Fundamentals of Cost Engineering in the Chemical Industry," Reinhold Publishing Corp. New York (1964).

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A P P E N D I X

Table A-I

ENGINEERING NEWS-RECORD BUILDING COST INDEX

U.S. Average 1950 to 1967

(Base: Year 1913 = 100)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
1950	356	356	360	363	364	373	378	383	393	397	390	391	375
1951	393	398	399	400	401	401	400	400	400	403	404	406	401
1952	406	406	407	408	410	412	414	422	424	425	426	425	416
1953	425	425	425	426	426	426	435	437	436	436	436	435	431
1954	436	437	437	437	438	440	444	456	454	455	456	457	446
1955	458	459	460	461	462	464	468	478	479	480	479	479	469
1956	480	483	483	486	487	489	489	491	500	500	500	500	491
1957	502	502	501	501	503	504	507	517	516	517	517	516	509
1958	517	516	516	517	519	521	524	526	535	537	535	535	525
1959	536	537	540	543	544	548	552	554	556	555	554	553	548
1960	554	555	555	556	560	561	563	562	563	561	561	562	559
1961	563	563	563	565	569	570	572	571	571	571	571	570	568
1962	571	573	575	576	579	580	583	586	586	585	584	584	580
1963	584	585	586	586	588	590	596	602	602	604	602	603	594
1964	604	604	606	607	609	612	615	616	617	617	616	617	612
1965	616	621	622	621	621	626	628	630	633	634	633	634	627
1966	635	641	643	649	652	656	657	659	660	659	659	658	
1967	660	661	663			675			686				

Source: Engineering News-Record

Table A-II

SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEX*
for
1958-1967

Time	National Average
August 1958	101.50
August 1959	103.65
August 1960	104.96
August 1961	105.83
August 1962	106.99
August 1963	108.52
August 1964	110.54
August 1965	112.57
August 1966	116.92
June 1967	119.11

* Public Health Service Publication No. 1069

Table A-III

THE HANDY-WHITMAN INDEX FOR WATER TREATMENT PLANTS

North Central Division
1950 to 1967
(Base: Year 1936 = 100)

	1950		1951		1952		1953		1954		1955		1956		1957		1958		1959		1960	
	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1
Large Treatment Plant	199	210	221	225	227	235	236	246	246	251	253	258	267	275	280	288	289	296	300	311	310	317
Small Treatment Plant	203	213	226	229	230	235	237	246	247	251	252	257	268	276	283	289	290	296	300	309	311	317

	1961		1962		1963		1964		1965		1966		1967	
	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1
Large Treatment Plant	313	315	317	324	324	330	332	340	341	350	353	368	367	380
Small Treatment Plant	313	315	316	322	322	327	329	336	338	346	350	362	361	374

Source: Handy-Whitman Index of Water Utility Construction Costs

Table A-IV

NONSUPERVISORY-WORKER AVERAGE HOURLY EARNINGS - IN DOLLARS*

Water, Steam, and Sanitary Systems Nonsupervisory Workers
1958 to 1967

Year	Average Earnings by Month in Dollars per Hour												Annual Average Dollars/Hour
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1958	1.96	2.00	1.97	1.96	1.96	2.00	2.00	2.00	2.02	2.03	2.08	2.05	2.00
1959	2.07	2.06	2.05	2.02	2.03	2.04	2.06	2.08	2.09	2.10	2.13	2.09	2.07
1960	2.11	2.12	2.12	2.14	2.13	2.15	2.18	2.18	2.18	2.21	2.23	2.22	2.17
1961	2.25	2.27	2.26	2.27	2.26	2.26	2.29	2.27	2.29	2.29	2.30	2.29	2.27
1962	2.28	2.30	2.30	2.32	2.31	2.33	2.34	2.32	2.34	2.33	2.37	2.36	2.33
1963	2.37	2.38	2.37	2.37	2.35	2.37	2.38	2.38	2.39	2.40	2.42	2.43	2.38
1964	2.42	2.44	2.43	2.44	2.44	2.44	2.44	2.43	2.46	2.45	2.48	2.47	2.44
1965	2.49	2.51	2.50	2.51	2.51	2.52	2.55	2.55	2.56	2.55	2.59	2.58	2.54
1966	2.61	2.65	2.63	2.67	2.66	2.65	2.69	2.67	2.70	2.72	2.74	2.74	n.a.
1967	2.76	2.79	2.76	2.79	2.80	2.80	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

n.a. means not available

*Source: U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings Statistics for the United States, 1948-67 (Vol. 13 No. 9)

Table A-V

TABLE OF AMORTIZATION FACTORS

20, 25, and 30-year periods
Three to five percent interest rate

Interest Rate	Amortization Factor*		
	20 years	25 years	30 years
3 %	.06722	.05743	.05102
3-1/2	.07036	.06067	.05437
4	.07358	.06401	.05783
4-1/2	.07688	.06744	.06139
5	.08024	.07095	.06505

* Annual payment necessary per $1.00 of debt for number of years shown to repay the debt.

Source: Marks' Mechanical Engineers' Handbook, Sixth Edition, McGraw Hill Book Company, Inc.

Table A-VI

RECOMMENDED MINIMUM BASIC FEES
Ohio Society of Professional Engineers

General Engineering Projects - Schedule 1

Intercepting, Relief, Storm or Sanitary Sewers

Pumping Stations

Ground or Underground Water Storage Facilities

Water Intakes and Sewage Outlets

Water, Sewage and Industrial Treatment Plants

Minimum Fees - Schedule 1
Cost of Construction

Less than $100,000 - Payroll costs plus a percentage

$100,000 to $500,000 - Base fee of 12% of $100,000
Plus 7.5% of amount over $100,000

$500,000 to $1,000,000 - Base fee of 8.4% of $500,000
Plus 6% of amount over $500,000

$1,000,000 to $5,000,000 - Base fee of 7.2% of $1,000,000
Plus 5.5% of amount over $1,000,000

$5,000,000 to $100,000,000 - Base fee of 5.84% of $5,000,000
Plus 5.25% of amount over $5,000,000

For alterations to above type projects, add 30% - 50% to fees shown above.

Table A-VII

SCHEDULE OF MINIMUM FEES FOR PROFESSIONAL ENGINEERS

As Published By The Missouri Society of Professional Engineers

ACTUAL COST OF CONSTRUCTION	BASIC MINIMUM FEE*
$ 750,000 to 1,000,000	5.75 %
500,000 to 750,000	6.25 %
400 000 to 500,000	6.75 %
300,000 to 400,000	7.00 %
250,000 to 300,000	7.25 %
200,000 to 250,000	7.75 %
150,000 to 200,000	8.25 %
100,000 to 150,000	8.75 %
50,000 to 100,000	10.00 %
25,000 to 50,000	11.00 %
10,000 to 25,000	12.00 %
Less than 10,000	Cost Plus 100%

* Basic fee shall be not less than the maximum calculated under the next lower total project cost bracket.

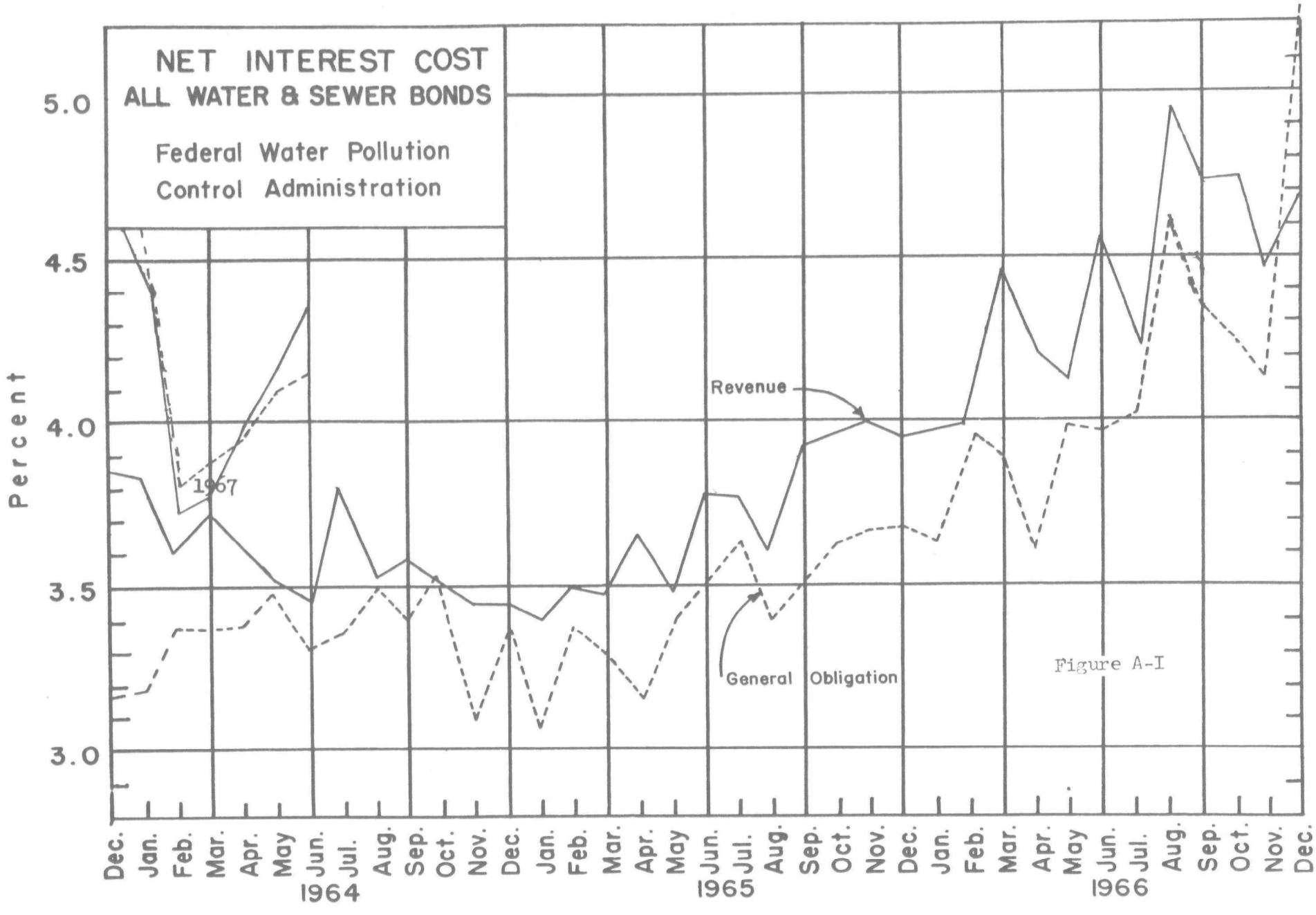
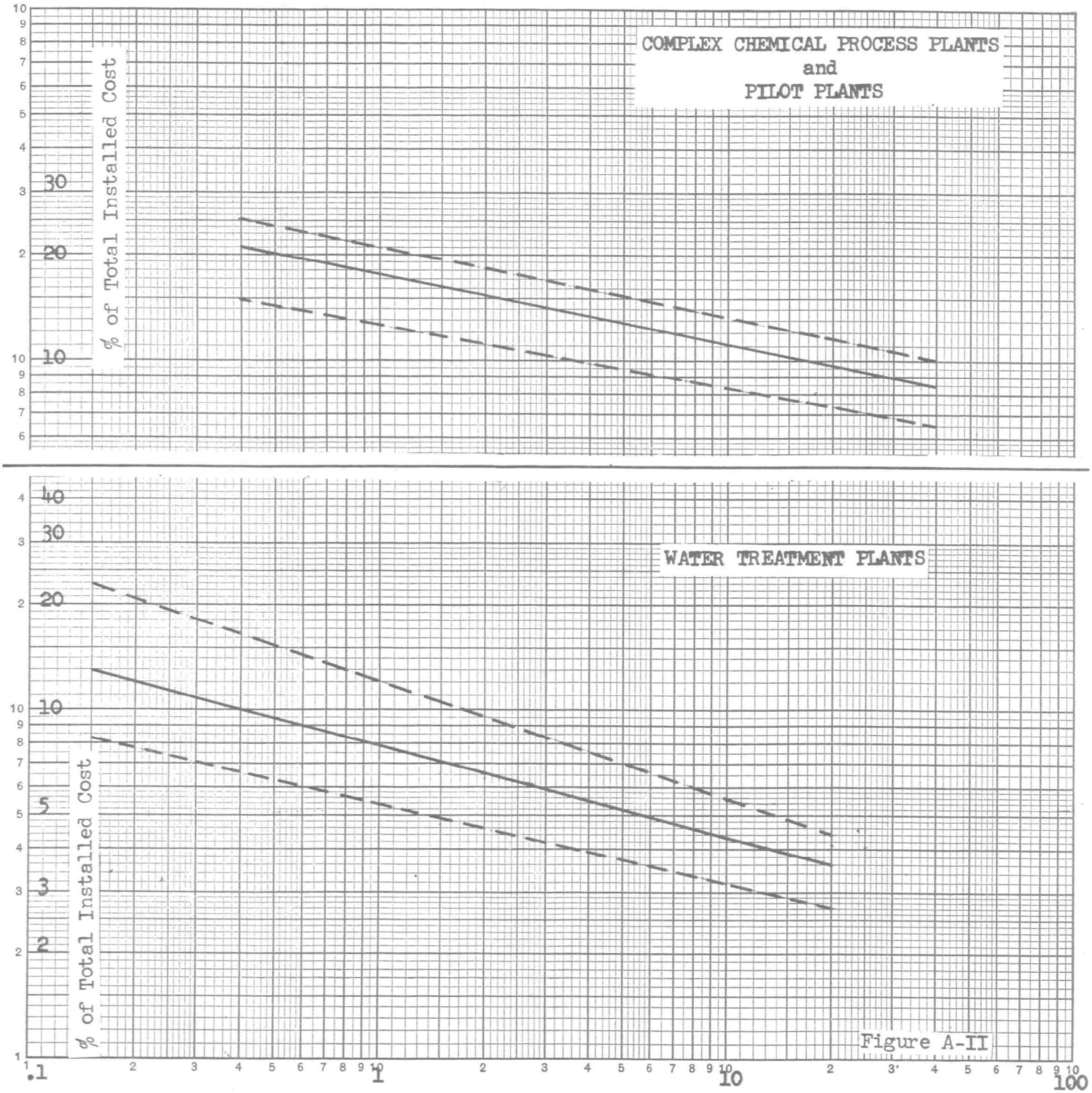


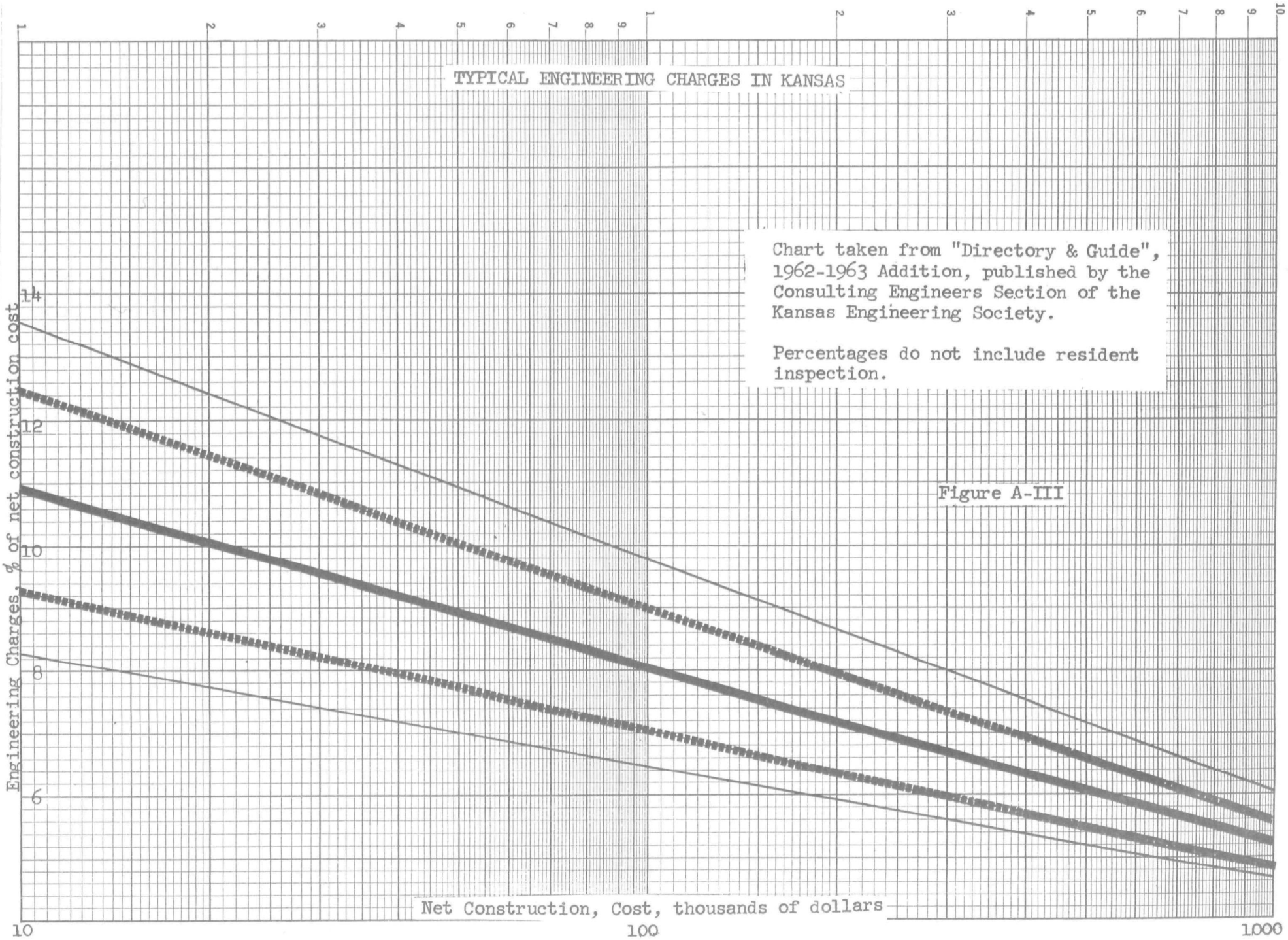
Figure A-I

All data for current year are provisional



INSTALLED COST IN MILLIONS OF DOLLARS

Source: Bauman, "Fundamentals of Cost Engineering In The Chemical Industry," Reinhold Publishing Corp., New York (1964).


TYPICAL ENGINEERING CHARGES IN KANSAS
Chart taken from "Directory & Guide", 1962-1963 Addition, published by the Consulting Engineers Section of the Kansas Engineering Society.
Percentages do not include resident inspection.
Figure A-III
Engineering Charges, % of net construction cost
14
12
10
8
6
Net Construction, Cost, thousands of dollars
10
100
1000

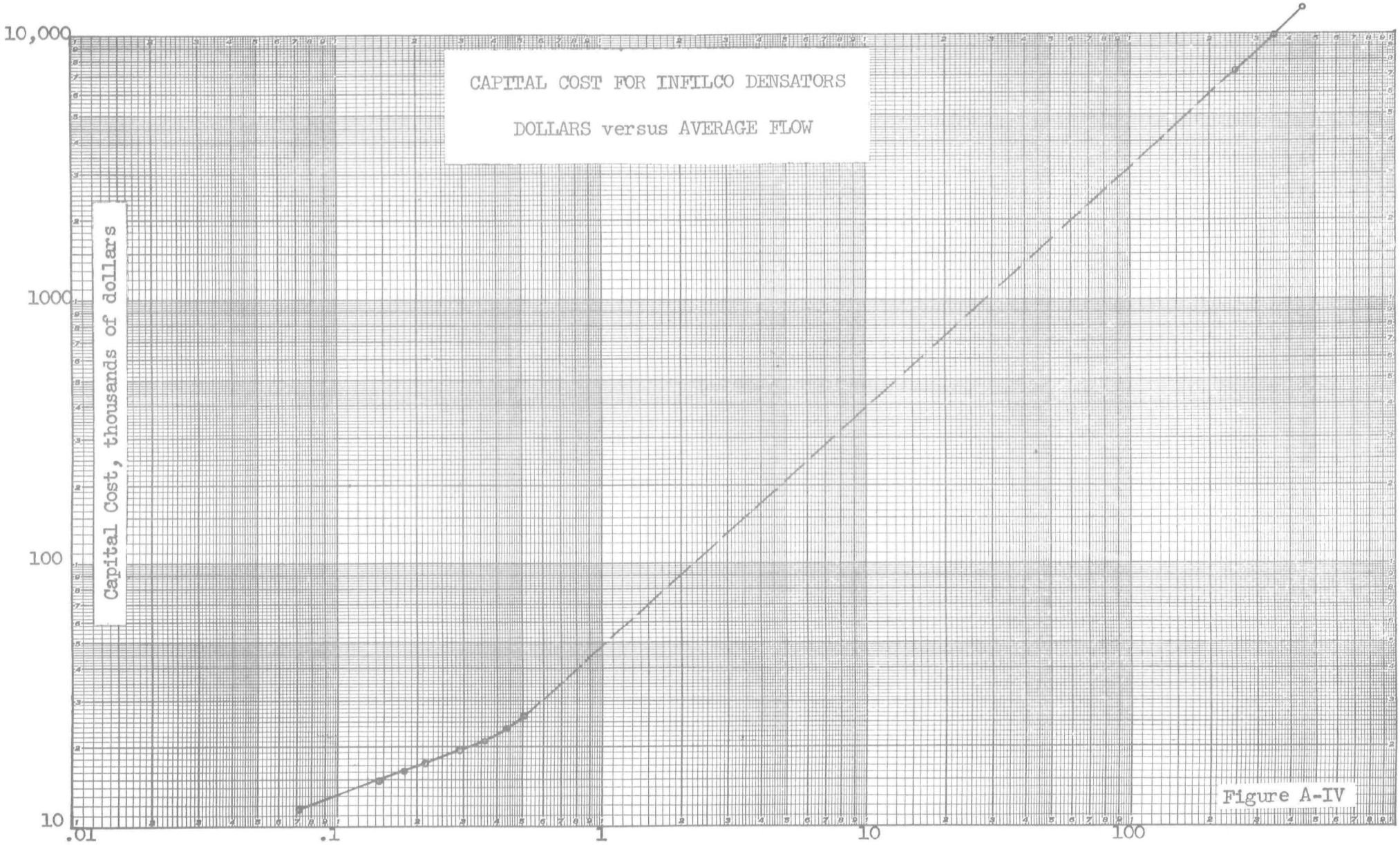


Figure A-IV

R. Smith 4/4/67