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ESTIMATING STAFFING AND COST FACTORS FOR SMALL WASTEWATER TREATMENT PLANTS LESS THAN 1 MGD

PART II. ESTIMATING COSTS OF PACKAGE WASTEWATER TREATMENT PLANTS

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Effective and efficient wastewater treatment is a function of both the quality of treatment and the cost of treatment. Although the actual quality and cost of treatment cannot be known until after a plant is in operation, estimates of both are needed at various times during the process of planning and designing a wastewater treatment system. The report describes costs, cost factors, data from manufacturers, and operating package plants.

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1. INTRODUCTION

1.1 General

Effective and efficient wastewater treatment is a function of both the quality of treatment and the cost of treatment. Although the actual quality and cost of treatment cannot be known until after a plant is in operation, estimates of both are needed at various times during the process of planning and designing a wastewater treatment system.

Preliminary cost estimates may be made early in the planning process by consultants or regulatory agencies to facilitate financial planning and to compare costs of alternate plants. Estimates of the quality of treatment would also be made to evaluate the ability of different alternatives to meet particular effluent quality standards.

These preliminary estimates are frequently based on studies of historical data. As the planning progresses, additional design data become available and more accurate estimates can be based on the specific design and specifications of each alternative treatment system.

Recent studies of construction and operating costs include a compilation and discussion of several studies by Smith[1] in 1968, a 1970 report of the operation and maintenance costs of municipal plants in the years 1957 through 1969 by Michel and Johnson[2], a 1970 report of construction costs of municipal plants in the years 1967-1969 by Michel[3], a 1970 article on costs and manpower for municipal plants by Michel[4], a 1972 article by Drews, Malan, Merring, and Moffatt on the performance and evaluation of the orbal extended aeration process[5], and a 1971 study of the construction, operation, and maintenance costs and manpower requirements of large conventional facilities by Black and Veatch Consulting

Engineers[6]. These studies have generally dealt with conventional wastewater treatment plants rather than package plants.

The National Sanitation Foundation (NSF) conducted research in 1965-1966 to establish methodology and criteria for evaluating the performance of extended aeration type package plants[7]. Subsequently, NSF conducted similar research on contact stabilization type package plants[8]. Since then, NSF has established Standard Number 40[9] and Basic Criteria C-9[10] relating to the evaluation of individual aerobic units and special processes or devices, respectively. NSF has evaluated (1) extended aeration plants from eighteen manufacturers, (2) special processes or devices used in treating wastewater from one manufacturer, and (3) individual aerobic wastewater treatment plants from two manufacturers; NSF is currently conducting a performance evaluation of package wastewater treatment plants from six manufacturers. A listing of these manufacturers may be found in Appendix A. The certification data is the property of the manufacturer and requests for data should be accordingly made to the appropriate manufacturers.

A few recent cost studies have been made of package plants. Drobny and Quasin[11] made a cost effectiveness study for the U.S. Navy of plants suitable for serving groups of 500 and 1000 men at advanced bases; they have published an article on this work[12]. A methodology was developed and utilized for evaluating plants when a number of criteria are to be considered (such as simplicity of installation, space requirements, etc.). Data on plant size, process description, volume, weight, fuel requirements, labor requirements and capital costs are presented in an appendix.

Snoeyink and Mahoney[13] studied commercially available wastewater treatment plants for the U.S. Air Force. Performance data is given for individual plants. Cost data is presented for the plants as a group and not for individual plants.

Goldstein[14,15] compiled cost and performance information on small units as part of a study of wastewater treatment systems for rural communities. Baily and Wallman[16] have also reported on household systems.

Seymour[17] presents information on the operation and performance of package plants under the jurisdiction of the Metropolitan Sewer District of Greater Cincinnati. The performance of three extended aeration package plants was studied over a three-week period and the results are reported in the article. Other recent studies on the performance of package plants have been made by Dague, Elbert, and Rockwell[18] Kugelman, Schwartz, and Cohen[19], Mulbarger[20] and Reid[21].

The University of Wisconsin is currently conducting a study of on-site domestic wastewater treatment systems[22]. The project is quite comprehensive in scope and includes studying "... criteria for proper site evaluation, equipment design, equipment installation, and long-term maintenance..."[22].

Some manufacturers have conducted private evaluation studies or funded independent studies of their package plants. Known studies are included in the bibliography, Appendix B, along with other cost and evaluation studies.

1.2 Classification of Costs

The total cost of a facility includes all costs of owning and operating that facility. Two broad classes of costs are capital related costs and cash operating costs. Capital related costs are those costs associated with investing money in a facility and include (1) the initial or first costs and (2) a return on the dollars tied up in the investment. Dollars invested in a facility cannot be invested in some other manner which would earn the investor a return. Hence, a cost of investing in a facility is a return on the invested dollars. This concept applies even when a governmental unit is the investor since the investment money comes from private individuals and organizations which could invest their money in projects earning a return.

Private ownership involves the additional capital related costs of paying income taxes associated with (2) above, earnings on the dollars tied up in the investment (if the plant is not 100% debt financed). Public ownership does not directly involve income taxes but it does affect local, state, and national sources of government revenues (see 23, chapter 11 for additional discussion).

Initial or first costs may be defined as[23]: "... the sum of the costs of purchase, freight in, sales tax, installation, and other such related initial expenditures including preproduction checking. In the case of a building, first cost includes architectural fees, legal fees, permit costs, landscaping costs, property taxes during construction, and interest lost during construction as well as the construction cost itself. Some expenditures, such as for an expanded facility, lead to an expanded need for the items which comprise working capital." In essence, first costs are all of those costs necessary to acquire a facility and put it in an operable condition. These costs, except for working capital, represent the purchase of a commodity which is "consumed" over a period of years.

Since only a relatively small amount of money is tied up in operating supplies and other working capital items, working capital costs were excluded from the study. "Interest lost during construction" or "interest during construction" (IDC) is an imputed return on the funds expended for physical assets during the time the assets are being constructed or erected and before they are put into service. Data on expenditures incurred more than one year prior to the first use of the plant were sought but such expenditures essentially did not occur. Hence, IDC costs are not included herein in the analysis of first costs.

The cost of replacing a major component or performing a major overahaul is similar to initial or first costs since the purchased "commodity" is consumed over a period of years. The replacement of minor itemc and minor repairs occur throughout the life of a facility and are relatively insignificant in size; hence, they are usually treated as cash operating costs.

Cash operating costs are those expenditures other than first costs and major replacements or overhauls. They include the day-to-day direct operating expenses such as operator labor, utilities, laboratory testing, etc., as well as maintenance, housekeeping or yardwork, and administration expenses.

1.3 Factors Influencing Costs

Several variables were expected to affect capital and operating costs. Two variables were thought to be particularly important: plant size and the amount of testing performed. Other variables which might influence costs include:

1. Type of basin or tank material
2. Type of aerobic digestion treatment process (including method of aeration)
3. Type of sludge collection system
4. Type and quantity of accessory equipment.

Plant size (measured in gallons per day of design capacity) is a major determinant of capital related costs. Size also influences cash operating expenses.

The amount of testing performed is a major factor in the variability of cash operating expenses. Testing affects not only testing related costs but also the amount of effort an operator can usefully expend in controlling the performance of a plant.

Plant tanks or basins may be made of plastic, fiberglass, steel, or precast concrete. The type of basin material may affect capital costs directly through the cost of the material and, indirectly, through the length of the life of the facility (some materials may last longer than others). Two other variables which might effect capital costs were suggested for steel tanks[24], quantity of steel and total length of weld. Data was not collected on either of these variables during the course of this study.

Two categories of treatment processes are included herein in operating plants: extended aeration and contact stabilization. A finer subdivision was not expected to improve the validity of the study significantly. Seven treatment process categories were utilized in classifying the data from manufacturers: contact stabilization, extended aeration (air diffusers), extended aeration (mechanical surface aerators), extended aeration (aspirating propellor or impellor), fill and draw, trickling filter, and miscellaneous types. Mechanical aeration usually involves agitation of the surface by some mechanical device. A diffused air system involves pumping air into the liquid by means of a motor, blower, and some type of air diffuser. Air may also be injected into the liquid by an aspirating propellor or impellor. The aeration system may affect both first costs and cash operating expenses and is probably the major plant component requiring overhaul and/or replacement.

Activated sludge may be returned to the plant aeration compartment from the final settling tank by gravity flow, by an air-lift return pump or by mechanical scrapers plus an air-lift return pump. The sludge return system influences both capital costs and cash operating expenses. In some units (primarily small size units) such as those involving membrane filters or fill and draw operations, sludge is not returned from one compartment to another.

Accessory equipment, such as comminutors, chlorinators, sludge holding tanks, etc., can have a significant impact on both capital related costs and cash operating expenses. What is standard equipment and what is an accessory may vary with manufacturers and may be dependent on plant size. In addition, the type and quantity of accessory equipment included in the list price of operating plants varies considerably. Differences in list prices arising because of varying amounts of accessory equipment would distort cost analyses; therefore list prices should be adjusted to reflect a basic plant.

1.4 Scope of Study

The general term "package plant" is applied to plants which are preengineered and use standardized equipment[8]. A sewage treatment system is usually designed by an engineer but the major component of the system may be a package plant. These plants may range from units with poured concrete basins and a package of standard equipment from a manufacturer to units fabricated at the manufacturer's factory but field erected at the site to units which are completely fabricated and assembled at the factory.

The term is broad enough to include units used on water craft as well as those used on land and units based on the chemical treatment of wastes as well as those based on anaerobic and/or aerobic digestion and a variety of other treatment methods.

Time did not permit nor did the project's scope require a consideration of all possible types of plants which are preengineered and which utilize standardized equipment. The following definition of a "package plant" was adopted for the purpose of this study and is not necessarily suitable for any other purpose:

> A complete wastewater treatment plant designed, fabricated, and assembled at a manufacturing location and transported to the treatment site where it is installed and connected to wastewater influent and effluent pipes.

Plants which were shipped to the site in a few pieces for final assembly were included in the study whereas units which were essentially field erected and/or had poured concrete basins were excluded from the study.

In addition to the limitations imposed by the above definition, only certain types of package plants were considered. In particular, only land-based plants designed for the treatment of sanitary sewage by an aerobic biological process were included in the study.

Manpower data were collected from operating plants and are included in the manpower portion of this report (Part I). A bibliography of cost and performance evaluation studies of package plants was compiled and is included as Appendix B. A third category of data is cost data.

Capital cost data was solicited from manufacturers of package plants. Capital cost and operating cost data were obtained from operating plants. These costs are the subject of the remainder of this report.

2. DATA FROM MANUFACTURERS

2.1 Introduction

Two primary types of data were solicited from manufacturers — list price data and data on the location of operating package plants. List price data on a large variety of plant sizes and from different manufacturers were needed to obtain enough data to make a meaningful analysis. The most direct sources of list price data are the manufacturers themselves; and only through manufacturers could data on all sizes manufactured by the individual manufacturer be obtained. Plant location data were solicited from manufacturers to supplement location data obtained from state pollution regulatory agencies. In addition to list price and location data, manufacturers were also asked for data on operation and maintenance costs, estimated life of plants, and reliability and/or operational data.

Manufacturers were promised that cost data would be kept confidential and not identified to specific companies; hence, list prices of specific plants are not given. Average list prices and standard deviations and equations obtained from regression analysis provide useful guidelines for preliminary cost estimating. Estimates of the list price of a specific plant which includes particular accessory equipment and is to be utilized in a given geographical area should be obtained directly from a distributor or manufacturer.

2.2 Data Collection Procedure

Names of potential package plant manufacturers were obtained from a variety of sources including Thomas' Register, the Water and Pollution

Control Equipment Review, Journal of the Water Pollution Control Federation, Water and Sewage Works, Water and Waste Engineering, and a number of reports on, or related to, package plants[7,11,25]. In April and May 1972, letters were sent to (potential) package plant manufacturers requesting capital cost data and other information on plants up to approximately 150,000 gpd (sample letter is shown in Appendix C). As the study progressed additional manufacturers were contacted. A second letter was sent in June and July to those companies which did not respond in any way to the first letter. A third letter was sent in September to all companies which had not responded to the first and second letters. Both telephone calls and letters were utilized to discuss the data request and to obtain additional data about the plants.

2.3 Data Analysis

The types of responses from manufacturers are shown in Table II-1.

Table II-1. Types of responses from potential manufacturers of package plants.

Manufacture package plants and sent cost data	38
Manufacture package plants and did not send cost data	12
Do not manufacture package plants now but plan to	4
Manufacture shipboard units	3
Manufacture nonaerobic package plants	5
Do not manufacture package plants	58
No response	71
Total	191

Companies which responded and indicated that they do manufacture or plan to manufacture package plants are listed in Appendix D. Appendix D also includes a list of companies manufacturing shipboard units and a list of companies manufacturing package plants which do not fall within the definition of a package plant as established for this study. Appendix E is a list of companies which did not respond or were not contacted but which were mentioned in other reports or in the literature as manufacturers of package plants (in a more general sense). Some companies were not contacted when available plant descriptions indicated they were not manufacturers of package plants, as defined for this report.

The lists of manufacturers of package plants should not be considered exhaustive. Although a thorough search was conducted for the names of manufacturers, experience indicates that not all were found, especially those of companies which serve a relatively local market.

The price figure selected for analysis was list price, FOB the manufacturer's plant. List prices were adjusted, if necessary, to exclude the cost of freight, service agreement, and plant installation. Since nearly all manufacturers provide some assistance in starting up the plant as part of the purchase price, no effort was made to eliminate this cost. Prices actually charged by dealers may be different than list prices because of competition.

Price variations may also arise because of differing amounts of accessory equipment. A meaningful analysis of plant cost data can be obtained only if the plants are similarly equipped or if the costs are adjusted to reflect costs of similarly equipped plants. Equipment features of a "basic" plant were established. The "basic" plant includes the necessary blowers, motors, control panels, and internal piping but does not include comminutors, chlorinators, chlorinator tanks, foam control equipment, stand-by equipment, extra grating nor sludge holding tanks. Digestors are included only when they are an integral part of the basin.

The price of a plant having more features was adjusted to yield an estimate of the cost of a "basic" plant. These derived costs are not exact, but they do provide a better basis for the comparison of costs among plants than do unadjusted costs.

List prices were expected to be a function of the variables: plant size (design capacity), type of process, type of sludge collection and return system, type of basin material, and the presence or absence of a digester. Table II-2 lists various types of treatment processes, sludge collection and return systems, and basin materials.

The data were analyzed in two ways: (1) a calculation of the mean (or average) list price and standard deviation of the average list price by size (design capacity) and (2) a regression analysis across sizes for various combinations of the other variables. An analysis involving only one or two package plants would yield no meaningful results. In addition, the results of an analysis involving the package plants of only one or two manufacturers might unintentionally lead to a breach of our promise to keep the cost data confidential to the extent of not associating prices with specific manufacturers. For these reasons, no grouping of the plants by size, etc. was analyzed unless the group contained plants from at least three different manufacturers.

Table II-2. Types of treatment processes, sludge collection and return systems, and basin materials.

Types of processes	Type of sludge collection and return systems	Types of basin materials
Contact stabilization	Air lift pump	Precast concrete
Extended aeration-air diffusers	Collector arms and air lift pump	Steel
Extended aeration-surface aerators	Gravity feed	Plastic and fiberglass
Extended aeration-aspirating propellor	No sludge return	
Fill and draw		
Trickling filter		
Miscellaneous		

An initial calculation was made of the mean and standard deviation for each plant size with all plants, regardless of type of process, sludge collection system or basin material lumped into one group for that size. Table II-3 shows the results in tabular form. The data set consisted of 381 plants from 38 manufacturers of which 56 (381-325) were in size groups consisting of plants manufactured by less than three different companies. Plots of the results are shown in Figs. II-1-3; the mean (list price) for a size is indicated by a short horizontal line and a vertical line indicates the mean list price plus and minus one standard deviation (if the list prices are normally distributed, the range of values between the mean-plus-one standard deviation and the mean-minus-one standard deviation includes approximately 2/3 of the population of list prices).

Table II-3. Means and standard deviations by plant size using data from 38 manufacturers.

Plant size, gallons per day	Number of plants in sample	Mean list price	Standard deviation
300	6	1,350	1,309
400	3	1,123	410
500	7	1,349	648
600	8	1,465	1,433
800	4	1,061	543
900	3	1,150	187
1,000	11	2,568	2,140
1,500	10	2,475	1,249
2,000	9	4,148	2,103
2,500	5	4,375	1,719
3,000	6	6,077	2,161
4,000	7	6,644	2,389
5,000	14	7,474	2,442
6,000	9	8,081	2,894
7,000	8	8,404	3,779
7,500	4	9,492	1,360
8,000	8	9,395	3,772
9,000	7	10,398	4,339
10,000	17	9,787	3,827
11,000	4	13,143	6,227
12,000	5	12,853	6,262
12,500	3	8,199	1,066

Table II-3. Continued.

Plant size, gallons per day	Number of plants in sample	Mean list price	Standard deviation
13,000	4	14,825	6,947
14,000	.4	15,209	6,981
15,000	15	12,730	5,961
16,000	3	12,895	2,162
17,500	4	12,847	4,924
20,000	16	14,268	4,029
25,000	8	13,730	2,534
30,000	14	17,555	4,155
35,000	8	18,690	3,840
40,000	14	22,711	5,876
45,000	5	22,538	4,328
50,000	17	29,497	10,930
60,000	7	29,904	8,342
70,000	5	33,121	7,935
75,000	4	39,570	11,363
80,000	3	37,016	10,590
90,000	3	39,268	11,627
100,000	11	47,177	25,105
200,000	6	44,195	8,453
300,000	5	50,502	12,492
400,000	5	57,106	14,689
500,000	6	104,215	97,020
	325		

Fig. II-1. Means and standard deviations of list price data from 38 manufacturers for plant sizes 0 to 9000 gallons per day.

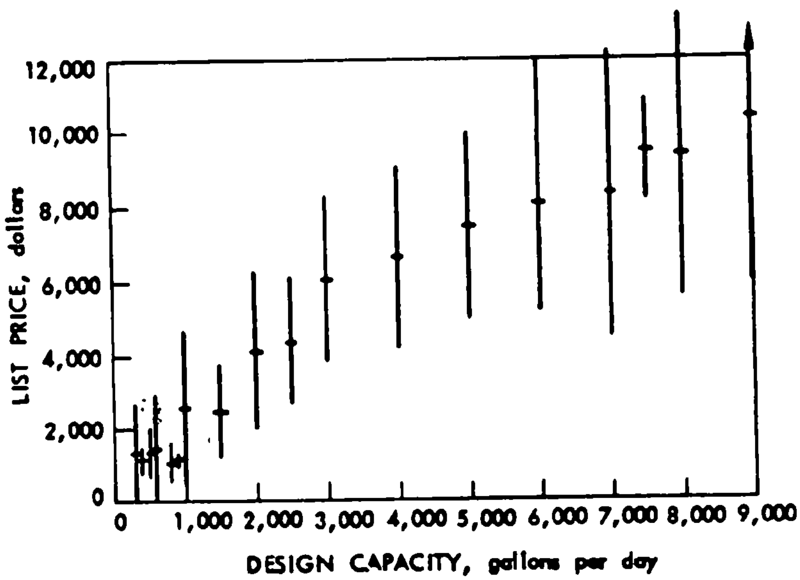
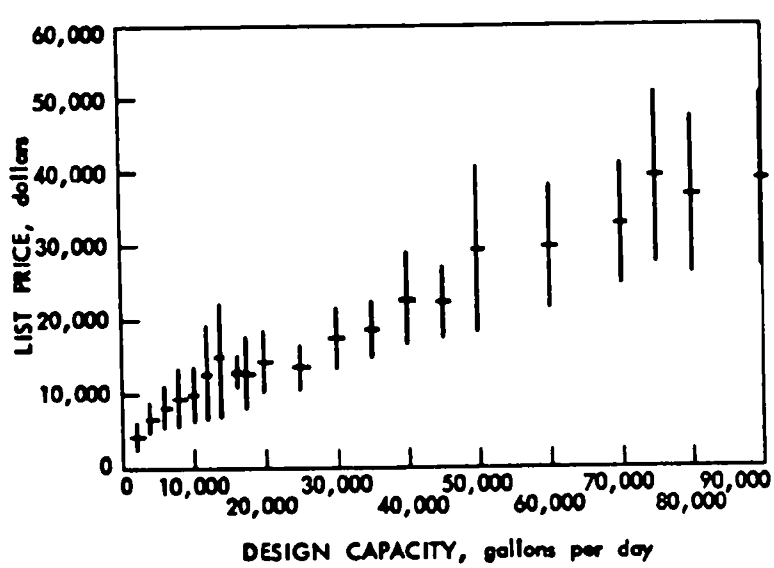
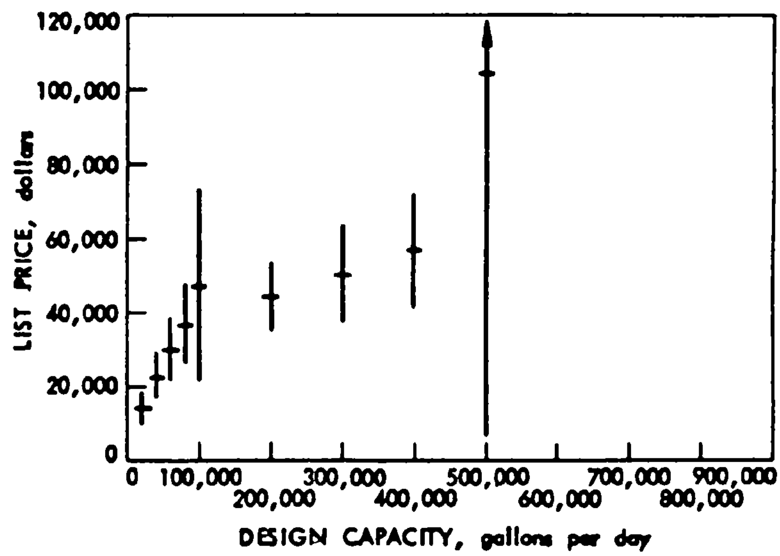


Fig. II-2. Means and standard deviations of list price data from 38 manufacturers for plant sizes 10,000 to 90,000 gallons per day and selected smaller sizes.



A review of the data indicated that the list prices of plants manufactured by some companies were nearly always higher or lower than those of the other plants in the same size groups. One cause seemed to be certain treatment processes: fill and draw, trickling filter, and

Fig. II-3. Means and standard deviations of list price data from 38 manufacturers for plant sizes 100,000 to 500,000 gallons per day and selected smaller sizes.



miscellaneous. List prices by specific manufacturers could also be consistently high or low because the prices include different services (service agreements, installation assistance, etc.) and/or different equipment which the author did not detect (and, therefore, did not adjust the list prices accordingly).

Plants utilizing treatment processes which are substantially different from the majority of plants can be justifiably eliminated. Therefore, plants based on treatment processes categorized as fill and draw, trickling filter, and miscellaneous were removed from the data set and a second calculation was made of the mean list price and standard deviation for each size group. The results of the second calculation are shown in Table II-4 and Figs. II-4-6. The data set consisted of 336 plants from 33 manufacturers, 55 (336-281) of which were in sizes groups consisting of plants from less than three different manufacturers.

Table II-4. Means and standard deviations by plant size using data from 33 manufacturers.

Plant size, gallons per day	Number of plants in sample	Mean list price	Standard deviation
300	4	743	255
500	7	1,349	648
600	6	873	321
900	3	1,150	187
1,000	9	2,178	2,148
1,500	9	2,139	696
2,000	7	4,248	1,848
2,500	4	3,836	1,416
3,000	5	5,593	2,019
4,000	6	6,002	1,838
5,000	11	7,358	1,806
6,000	7	7,073	1,747
7,000	5	7,570	2,149
7,500	4	9,492	1,360
8,000	6	7,947	2,121
9,000	5	8,676	2,541
10,000	14	9,325	2,623
12,000	4	10,216	2,436
12,500	3	8,199	1,066
14,000	3	11,812	1,966
15,000	14	11,696	4,584

Table II-4. Continued.

Plant size, gallons per day	Number of plants in sample	Mean list price	Standard deviation
16,000	3	12,895	2,162
17,500	4	12,847	4,924
20,000	16	14,268	4,029
25,000	8	13,730	2,534
30,000	14	17,555	4,155
35,000	8	18,690	3,840
40,000	14	22,711	5,876
45,000	5	22,538	4,328
50,000	17	29,497	10,930
60,000	7	29,904	8,342
70,000	5	33,121	7,935
75,000	4	39,570	11,363
80,000	3	37,016	10,590
90,000	3	39,268	11,627
100,000	10	44,344	24,540
200,000	6	44,195	8,453
300,000	5	50,502	12,492
400,000	5	57,106	14,689
500,000	6	104,215	97,020
	281		

Fig. II-4. Means and standard deviations of list price data from 33 manufacturers for plant sizes 0 to 9000 gallons per day.

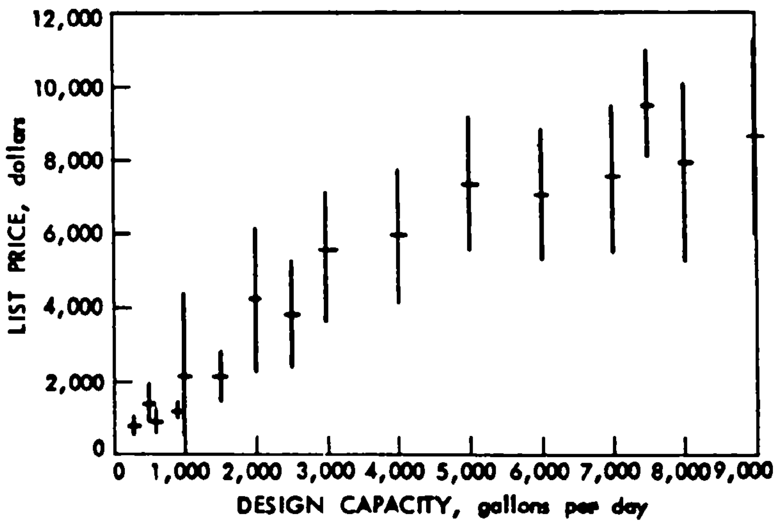
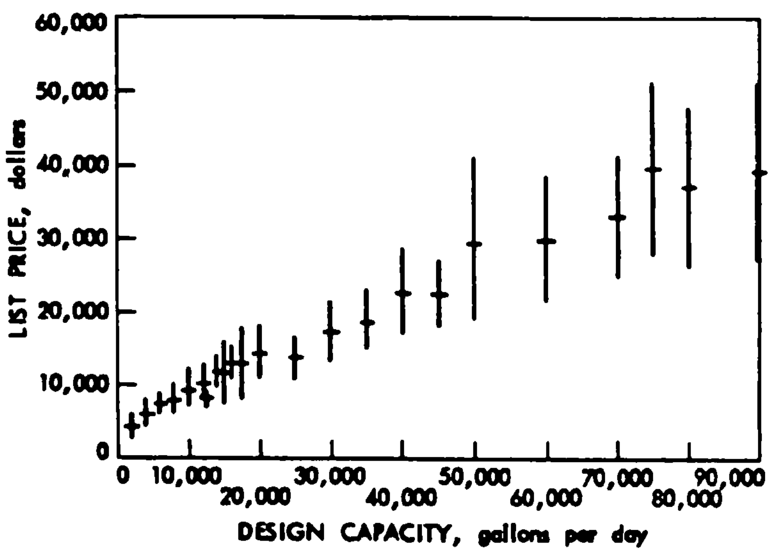
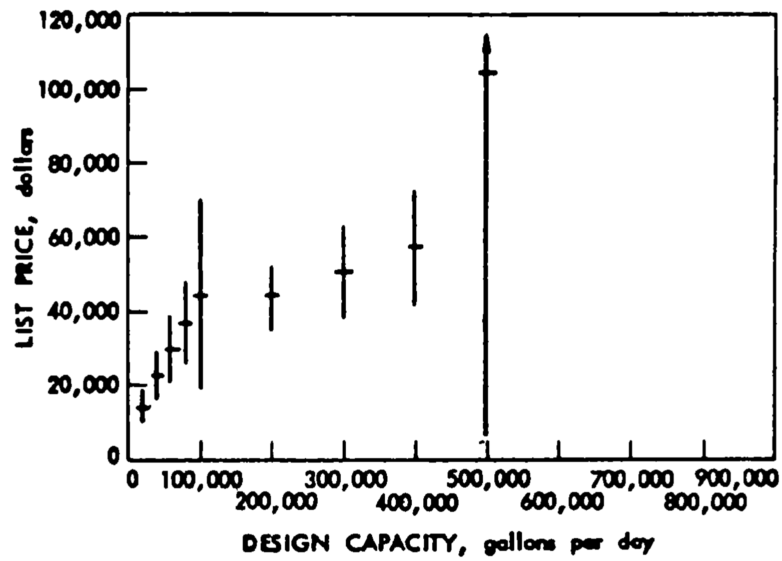


Fig. II-5. Means and standard deviations of list price data from 33 manufacturers for plant sizes 10,000 to 90,000 gallons per day and selected smaller sizes.



There were not enough data points for any given plant size to calculate means and standard deviations for any given combination of class variables (type of process, type of sludge collection system, type of basin material, and presence or absence of digester). Only rarely were there sufficient data points to calculate a separate mean and

Fig. II-6. Means and standard deviations of list price data from 33 manufacturers for plant sizes 100,000 to 500,000 gallons per day and selected smaller sizes.



standard deviation for list price vs size and each of two types of processes. Consequently, an attempt to determine the effect of the several class variables was left to a regression analysis.

Figures II-3 and II-6, especially, indicate a nonlinear relationship between list price and size. A number of studies[1,3,26,27] used a cost-size relationship of the form:

$$Y = AX^B$$

where

Y = list price in dollars,

X = plant size in 100's of gallons per day, and

A, B = constants.

A graphic representation of this type of relationship between variables is best expressed by a plot on log-log paper. If the data points form a reasonably straight line, then the formula will do a reasonable job of relating list price to plant size. Figure II-7 is a plot (on log-log

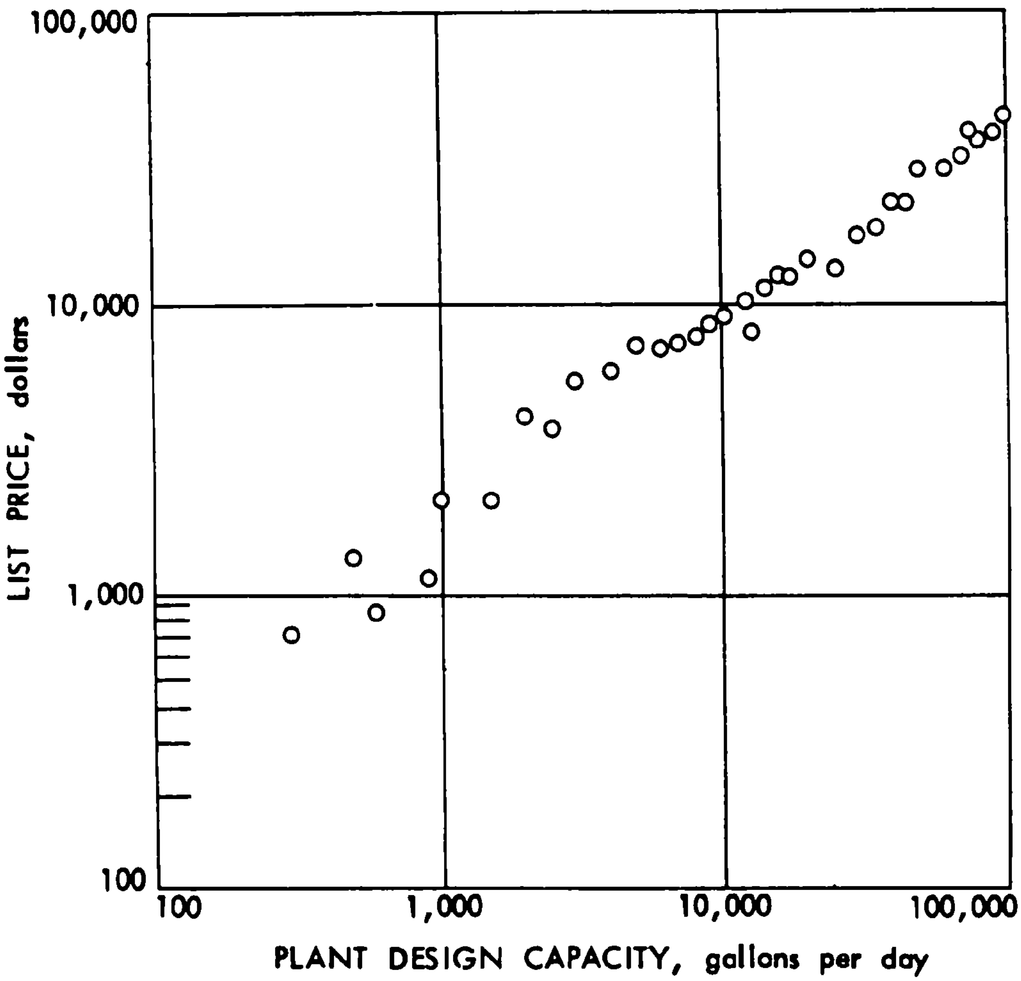


Fig. II-7. Log-log plot of mean list price vs plant design capacity for plants from 33 manufacturers.

graph paper) of the mean list price of each size group (using the data sèt involving 33 manufacturers).

Since the data in Fig. II-7 indicate a linear relationship, a regression analysis was performed using the logarithmic transform of the list price-plant size relationship:

$$Y = AX^B$$

i.e.,

$$\log Y = \log A + B \log X$$

The regression analyses were performed on only the 336 plants from the 33 manufacturers (this excludes plants utilizing fill and draw, trickling filter, and miscellaneous treatment processes).

A preliminary review of the data indicated that there were less than three different manufacturers represented in the "extended aeration – surface aerators" and exactly three represented in the "extended aeration – aspirating propellor" treatment processes; therefore, all extended aeration subclassifications were discarded and all extended aeration plants included in a single group. As a result, the number of types of treatment processes was reduced to two, contact stabilization and extended aeration.

The equation, $Y = AX^B$, expresses a relationship between list price and plant size. The effect of the several class variables (type of treatment process, type of sludge collection and return system, type of basin material, and presence or absence of a digestor) is obtained by fitting the equation to several subsets of data, each data subset containing only those plants with specified characteristics.

Data from all 33 manufacturers were grouped and the effects of manufacturer on the list price-plant size relationships were not calculated.

Table II-5 shows the results of the regression analyses. A regression equation was fitted to each possible combination within each of the following groups of class variables:

1) treatment process
2) treatment process and sludge collection and return system
3) treatment process, sludge collection and return system, and basin material

Table II-5. Regression analysis information for the list price-plant size data from the 33 manufacturers.

[a]Type of treatment process	[b]Type of sludge collection and return system	[c]Type of basin material	[d]Presence or absence of a digester	Number of observations in data set	Smallest plant in data set (100's of gpd)	Largest plant in data set (100's of gpd)	Log A	A	B	r^2
–	–	–	–	336	2	7500	2.61893	416	0.65426	0.91
Contact s.	–	–	–	51	100	7500	3.06028	1149	0.49551	0.65
Extended a.	–	–	–	285	2	5000	2.56817	370	0.68234	0.91
Extended a.	Air lift	–	–	193	3	1000	2.58847	388	0.66737	0.90
Extended a.	Mech.	–	–	Same as "extended a., mech., steel, –"						
Extended a.	Gravity	–	–	22	4	600	2.41442	260	0.81320	0.92
Contact s.	Mech.	Steel	–	41	100	7500	3.25193	1786	0.41090	0.86
Extended a.	Air lift	Concrete	–	Same as "extended a., air lift, concrete, no"						
Extended a.	Air lift	Steel	–	136	5	1000	2.77091	590	0.60349	0.90
Extended a.	Air lift	Plastic	–	Same as "extended a., air lift, plastic, no"						
Extended a.	Mech.	Steel	–	50	20	5000	3.23973	1737	0.44014	0.90
Extended a.	No return	Plastic	–	Same as "extended a. – no return, plastic, no"						
Contact s.	Mech.	Steel	Yes	35	100	7500	3.25347	1793	0.40719	0.85
Extended a.	Air lift	Concrete	No	53	5	1000	2.40683	255	0.70629	0.97
Extended a.	Air lift	Steel	No	124	5	1000	2.75771	572	0.61310	0.90
Extended a.	Air lift	Plastic	No	4	3	10	2.61885	416	0.35917	0.84
Extended a.	Mech.	Steel	Yes	31	20	5000	3.27930	1902	0.41974	0.90
Extended a.	No return	Plastic	No	18	2	25	2.43166	270	0.74143	0.80
–	Air lift	–	–	199	3	5000	2.60406	402	0.65888	0.91
–	Gravity	–	–	22	4	600	2.41442	260	0.81320	0.92
–	–	Concrete	–	65	5	5000	2.30712	203	0.76187	0.95
–	–	Steel	–	247	5	7500	2.87582	751	0.55755	0.89
–	–	–	No	248	2	5000	2.53665	344	0.69274	0.93

[a]Contact s. = contact stabilization
Extended a. = extended aeration

[b]Air lift = air lift pump
Mech. = mechanical collection and air lift sludge return
Gravity = gravity flow return
No return = no return of sludge

[c]Concrete = precast concrete basin
Steel = steel basin
Plastic = plastic or fiberglass basin

[d]Yes = with digester
No = without digester

4) treatment process, sludge collection and return system, basin material, and presence or absence of a digester.

A regression equation was also fitted to the data for all 336 plants.

A number of the data subsets contained no data; for instance, there were no plants using the contact stabilization treatment process and a gravity feed sludge collection and return system. (Further classification by basin material and digester also results in empty data sets.) The regression equations for data subsets consisting of plants manufactured by less than three different companies are not reported to preserve the confidential nature of the data.

The regression equations for which the square of the correlation coefficient, r^2, are less than 0.80 are not reported except the equation for all contact stabilization plants. The equation for all contact stabilization plants is included since that data subset (all contact stabilization plants) is an important major subset.

The value of r^2 is a measure of the total variation of one variable (list price) which can be accounted for by the other variable (plant size). Although the r^2 values were calculated from the regression equation $\log Y = \log A + B \log X$ rather than $Y + AB^X$, they still provide some indication of the amount of variation in plant cost which can be explained by plant size. For example, the regression analysis of the data subset "extended aeration, air lift sludge return system, precast concrete basin and no digester" yielded an r^2 value of 0.97. Such a high r^2 value means that most of the variation in list prices can be explained in terms of plant size even though data from at least three different manufacturers are included in this data subset.

A dash line under a class variable, in Table II-5, means that no distinction is made between plants on the basis of that class variable for the particular regression analysis. For example, line one shows "-,-,-,-" indicating that all plants, regardless of treatment process, sludge collection and return system, basin material, and presence or absence of a digester are included in the data set; line nine shows "extended a., air-lift, steel, —", indicating that all plants with the following characteristics are included in the subset: extended aeration treatment process, air-lift pump sludge collection and return system, and a steel tank, with or without a digester; the last line shows "-,-,-,NO" indicating that the data set consists of all plants without a digester regardless of type of treatment process, sludge collection system, and basin material.

The values of log A, A, and B are given for each regression equation. A user may estimate list price by either equation:

$$Y = AX^B$$

or

$$\log Y = \log A + B \log X$$

or by reading it from a graph. Figures II-8-13 are plots of the regression equations. The lines are drawn between the smallest and largest plants in the data subset (within the limits of the graph paper).

Data on large size extended aeration-gravity return plants (Fig. II-9) came from one manufacturer; without data from this manufacturer the plants would have ranged in size from 400 gpd to 1500 gpd.

Figure II-13 indicates plants using precast concrete basins cost less than those with steel basins for sizes up to approximately 50,000 gpd.

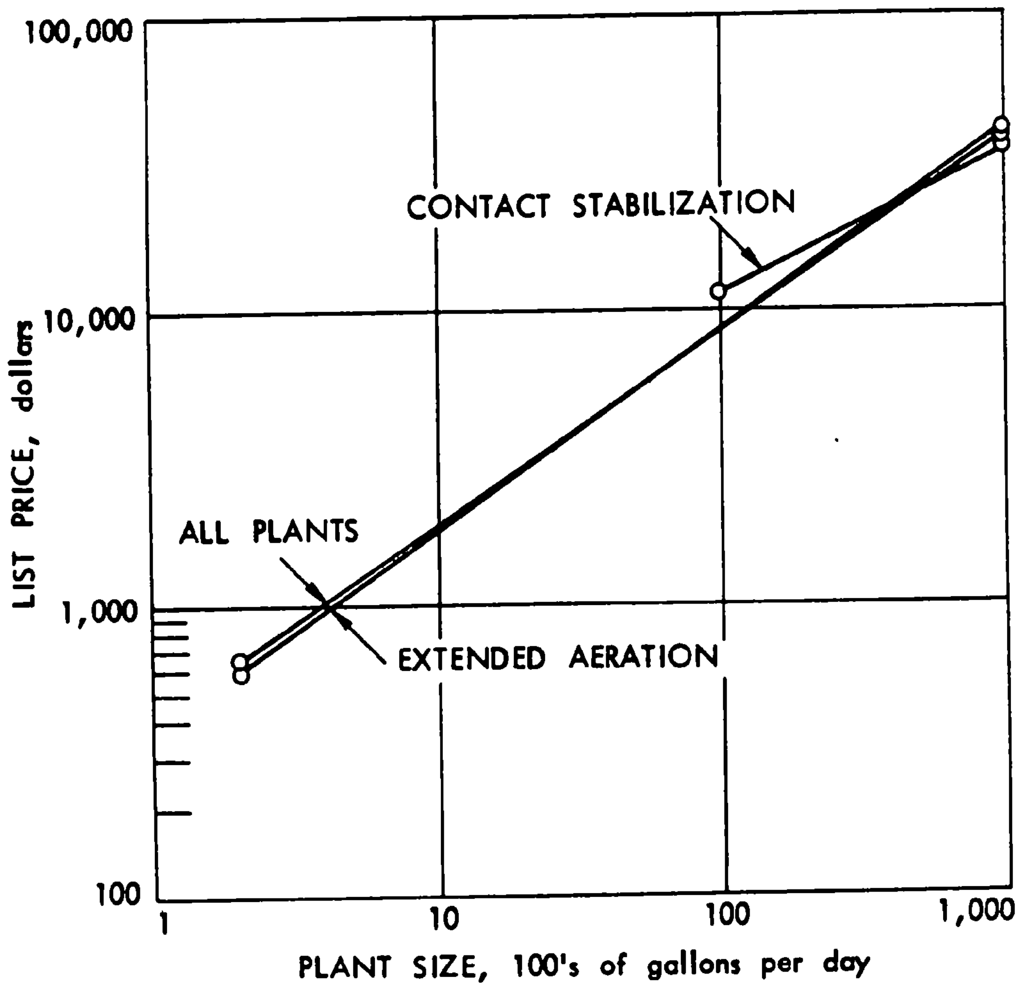


Fig. II-8. Regression lines for list prices of all plants and for list prices by type of treatment process.

Manufacturers were asked to send list prices FOB the factory; hence, these prices do not include the costs of transportation, excavation, and installation of the plant. These latter costs would, of course, need to be considered in estimating the total capital cost of a package plant.

One further consideration should be mentioned. Since the probable average service life of plants with steel basins may differ from that of plants with precast concrete basins, any comparison of these plants

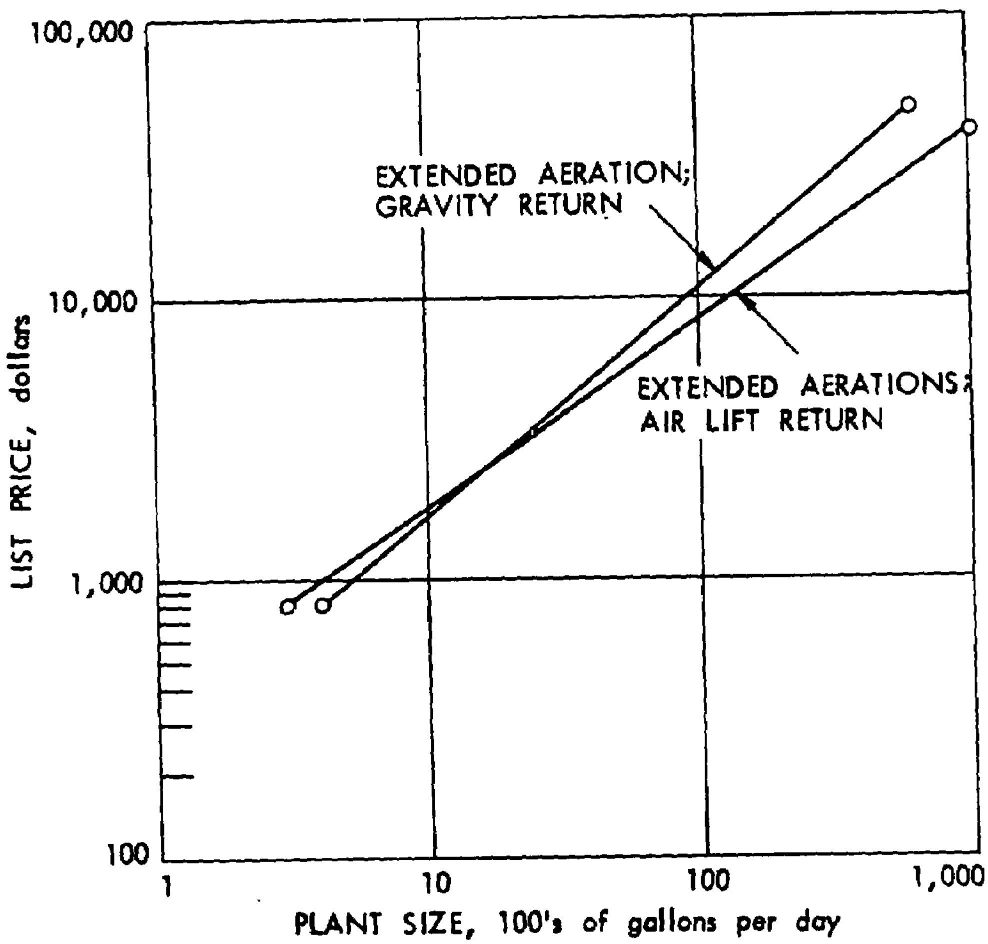


Fig. II-9. Regression lines for list prices subdivided by treatment process and sludge collection and return system.

must be made on the basis of annual equivalent costs. The annual equivalent cost of a piece of equipment is that uniform annual dollar amount over the life of the equipment which will recover the first cost of the equipment plus a return each year on the unpaid balance. If the estimated net salvage value is zero, the annual equivalent cost may be computed by multiplying the first cost by the capital recovery factor:

$$AEC = Y(a/p)^{i}_{n}$$

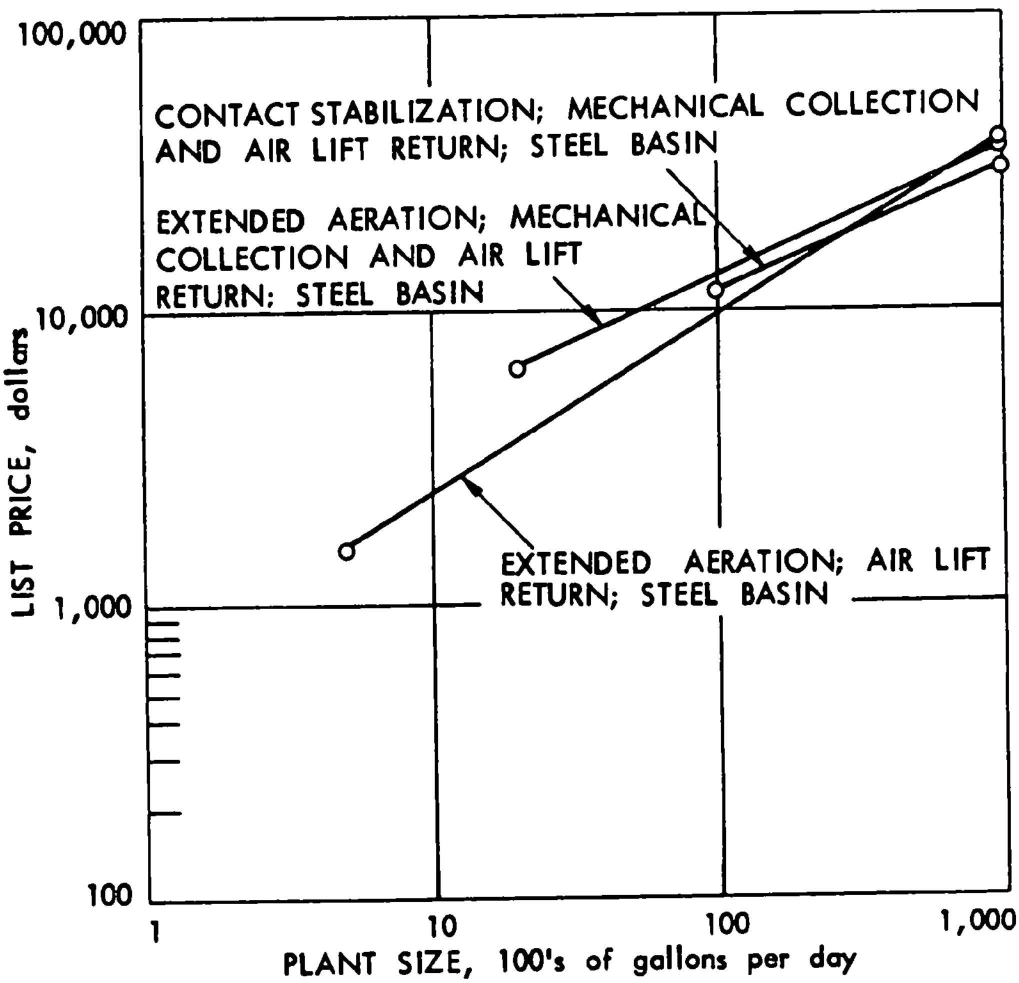


Fig. II-10. Regression lines for list prices subdivided by treatment process, sludge collection and return system, and type of basin material.

AEC = annual equivalent cost

Y = as before

$(a/p)_n^i$ = capital recovery factor

i = rate of return

n = probable average service life

Since the list price-plant size relationship

$$Y = AX^B$$

was used,

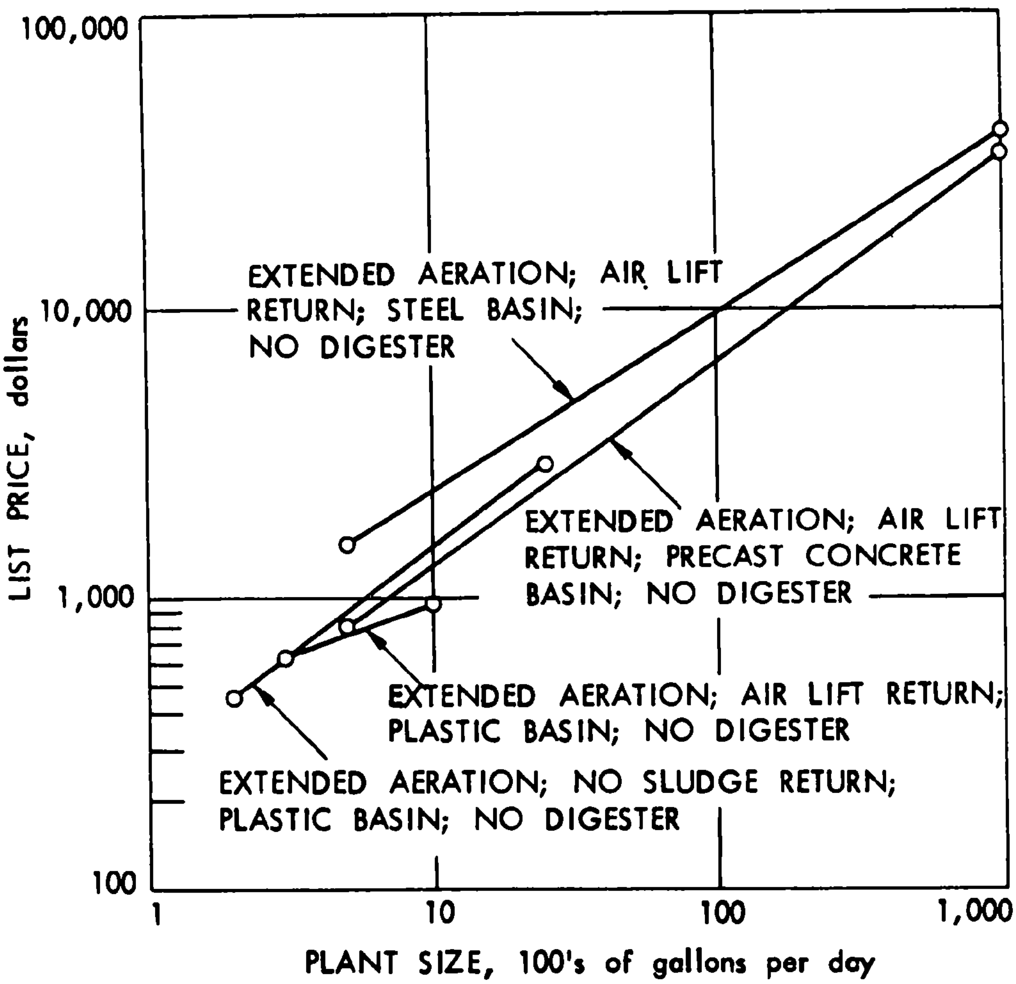


Fig. II-11. Regression lines for list prices subdivided by type of treatment process, sludge collection and return system, basin material, and no digester.

$$AEC = AX^B (a/p)_n^i$$

and the plot of AEC (based on only list price) is a straight line on log-log graph paper. This straight line will have the same slope as the line from the equation $Y = AX^B$ but it will be located a constant distance below $Y = AX^B$. An AEC for concrete basins and for steel basins is shown in Fig. II-14 using a rate of return of 6% and a life of 40 years and 30 years, respectively; the use of these figures for probable average service lives should not be construed to mean these

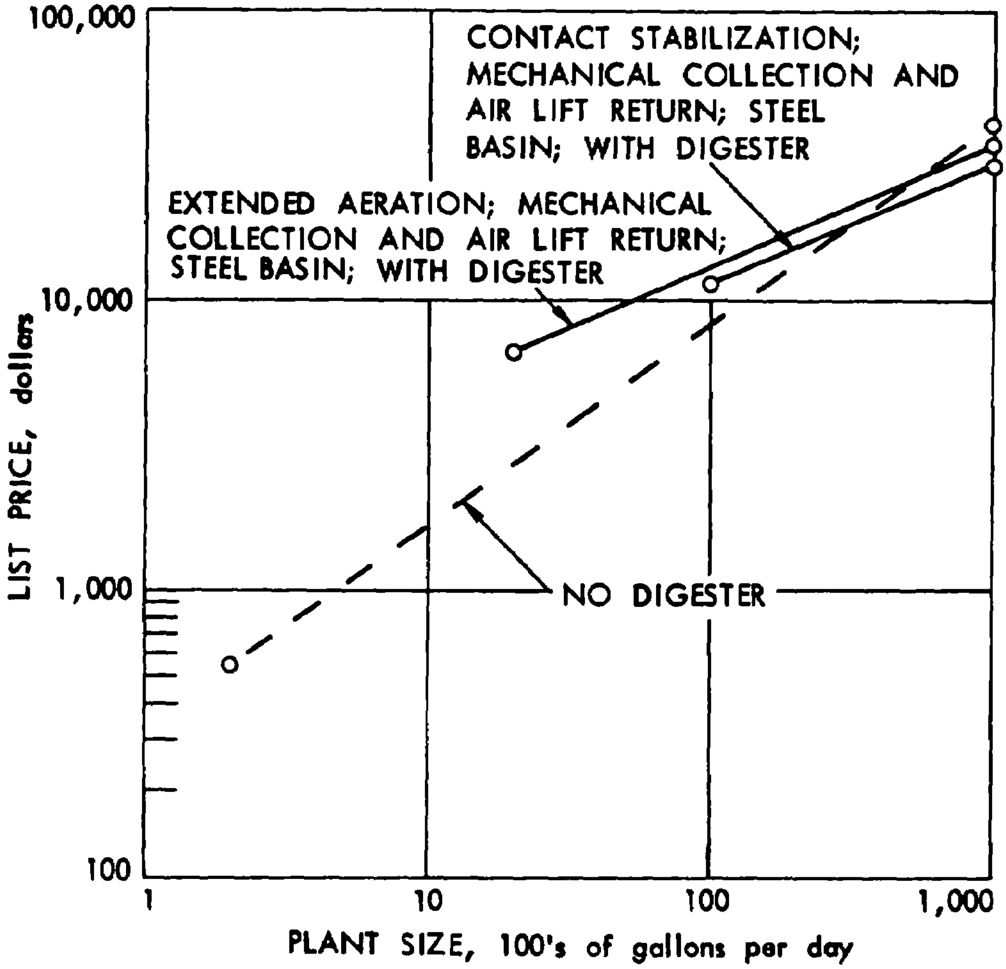


Fig. II-12. Regression lines for list prices subdivided by type of treatment process, sludge collection and return system, basin material, and with a digester and for all plants without a digester.

are actual estimates of probable average service lives. Similarly, the choice of a 6% rate of return is arbitrary; the rate of return to use will vary according to time and particular conditions.

2.4 Summary

Table II-5 and Figs. II-8-13 present the regression analyses of package plant list price data from the manufacturers. The data were

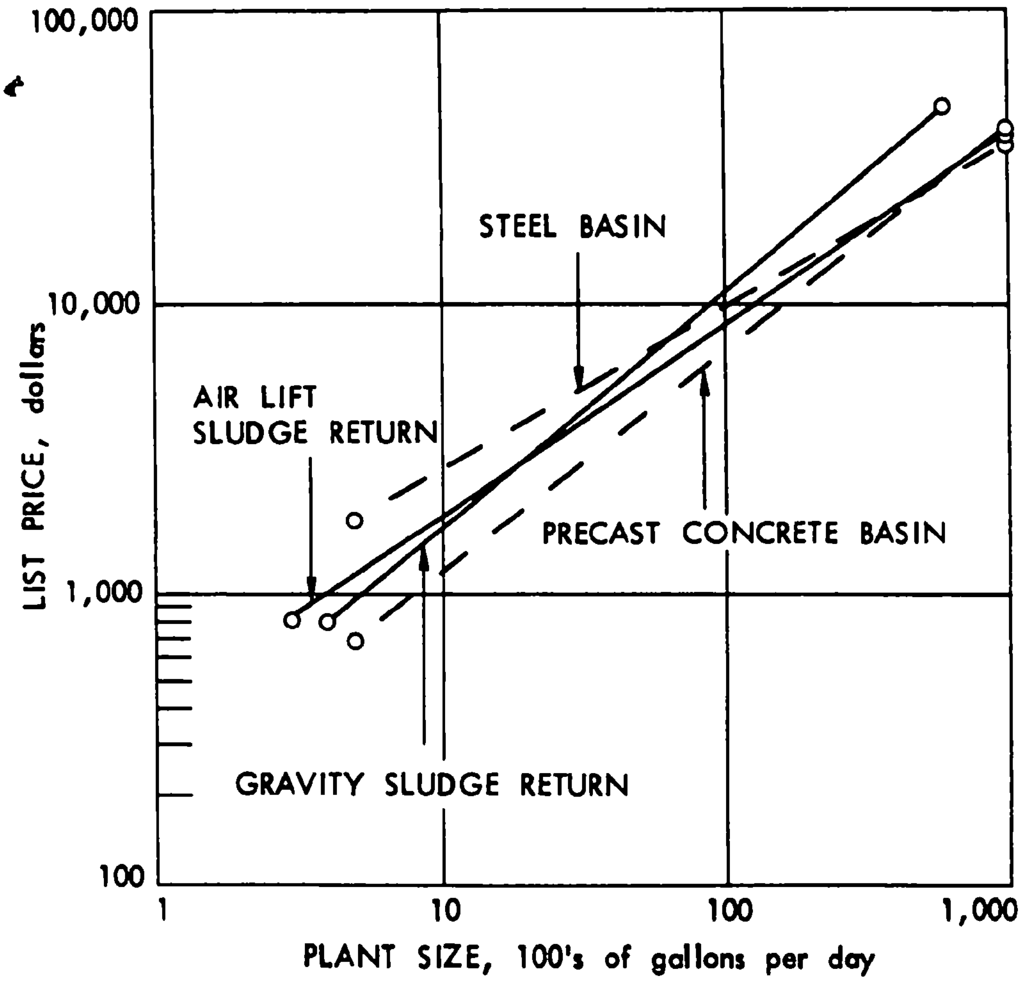


Fig. II-13. Regression lines for list price data subdivided by sludge collection and return system and by type of basin material.

grouped in a large number of ways for analysis. The analysis of a number of these data subsets yielded correlation coefficients, r^2, of 0.80 or higher. The corresponding regression equations should be reasonably valid for estimating the list prices of package plants.

The data in this portion of the study were list prices FOB the factory. List price is, however, only a part of the total capital cost of a package plant. Other costs, such as engineering and design, transportation, site preparation, etc., should be estimated and added

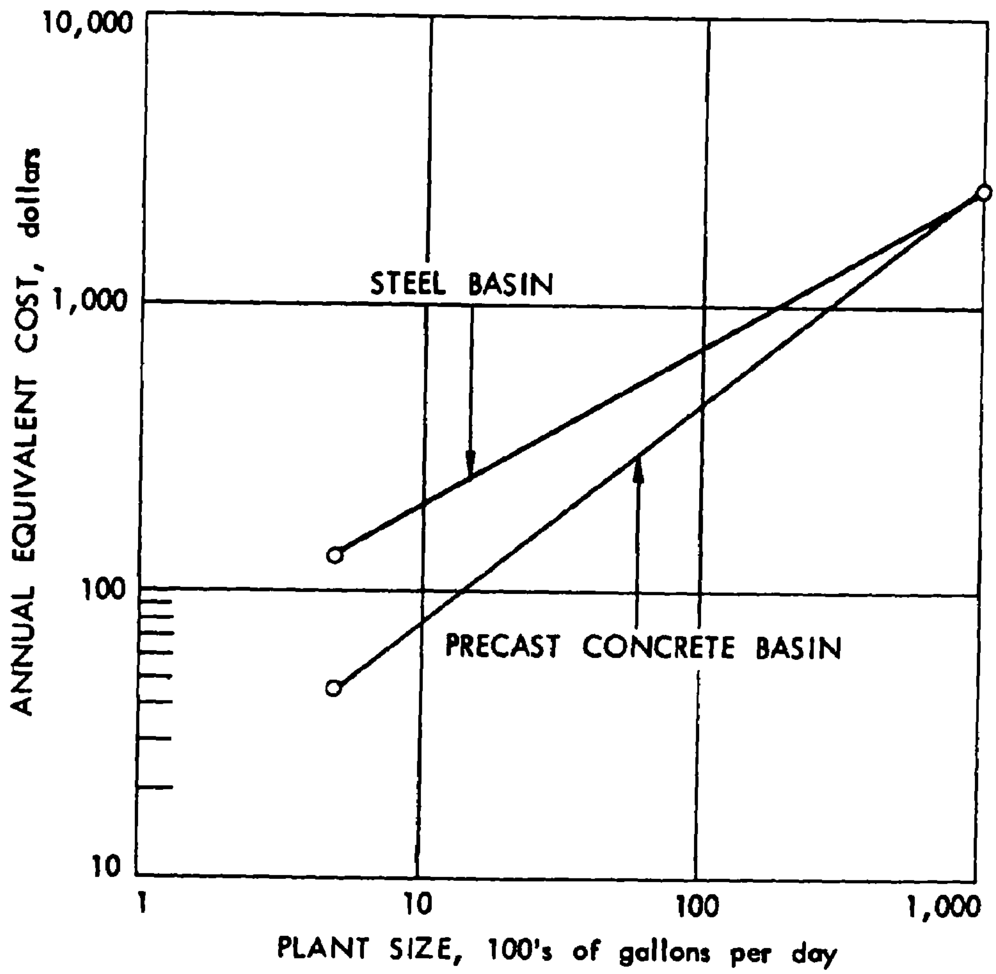


Fig. II-14. Annual equivalent costs of precast concrete basins and steel basins.

to the list price to obtain total capital costs. Also, the actual price of a plant may vary some from the list price due to competition and local conditions.

3. DATA FROM OPERATING PACKAGE WASTEWATER TREATMENT PLANTS

3.1 Introduction

Field visits were made to operating package plants to collect empirical data on manpower requirements and capital and operating costs. These plants were located in Illinois, Iowa, Kansas, Minnesota, Missouri, Oklahoma, Texas, and Wisconsin. Results of the analyses of these data are relevant only for these states and may be relevant for only those states with similar climates, soil conditions, testing and reporting requirements, etc.

3.2 Data Collection Procedure

The locations of operating package plants were solicited from package plant manufacturers, state environmental protection agencies, package plant distributors, and package plant operators. Plants to visit were selected to provide data on plants located in several different states, manufactured by a number of different companies, and used by a variety of customers.

Package plant owners (or operators) were contacted by letter and/or telephone to determine whether their plant was a package plant according to our definition and to request permission to visit the plant and locate data (sample letter in Appendix C). A personal visit was made to each of the selected plants by a research assistant to collect the desired data.

Data collection forms were used to facilitate the orderly collection of data. The forms for collecting manpower data are modified versions of the forms used to collect similar data from municipal plants (see Appendix F). Data for the cost study portion were divided into seven major categories (see Appendix G):

1. General information
2. First costs
3. Major replacement costs
4. Operating expenses
5. Maintenance expenses
6. Housekeeping or yardwork expenses
7. Administrative expenses

A rather detailed listing of cost items was made to maximize the usefulness of the data; data collected in detail can always be aggregated in various ways in the analysis process whereas data collected to gross can seldom be further subdivided. In addition, the collection of data in detail assists in the correct classification of the data and reduces the chances of costs being placed in the wrong major category.

A number of wastewater treatment facilities consist of a package plant followed by a lagoon or other treatment process. To facilitate the separation of costs between the package plant itself and other treatment facilities, a limited amount of data was collected on any other treatment facilities at the site.

3.3 Data Analysis and Results

Operating plants were visited in eight states. In a number of instances, insufficient data were obtained from owners and/or operators to warrant inclusion in the analysis. Table II-6 shows the number of operating plants included in the analysis by state and type of facility

Table II-6. Operating package plants visited by state and use.

State	Type of facility serviced by the plant					Testing and reporting required by state for plants visited
	City or subdivision	Mobile homes	Office	Miscellaneous	Total	
Illinois	7	1	2	3	13	Yes
Iowa		2		1	4	No
Kansas	2				2	No
Minnesota	2	3			5	Yes
Missouri	1	1	2 (Same location)	3	7	Some
Texas		1			1	Yes
Wisconsin	2	–	–	–	2	Yes
Total	14	8	4	6	34	

serviced and whether the state required the operators to perform tests and send reports to a state agency.

Table II-7 is a list of the number of plants by manufacturers and Table II-8 shows the number of plants by size and treatment process for those plants included in the analysis.

Although each of the 34 plants included in the data analysis contributed some data points, none contributed data to each and every subitem. Consequently, only a few specific subitems were analyzed in addition to the regression analysis of the total reported capital costs and the total reported operating expenses. The following data groups were analyzed:

Table II-7. Manufacturers of the operating package plants visited.

Manufacturer	Number of plants
BiO_2	1
Can-Tex	2
FMC-Chicago Pump	4
Clow	6
Davco	1
Dravo	1
Jet Aeration	1
Lyco	1
Permutit Sybran Corp.	1
Smith & Loveless	11
Walker Process	4
Water Pollution Control	1

1. Purchase price plus freight plus sales tax adjusted to 1972 dollars using the Environmental Protection Agency — Sewage Treatment Plant Index (EPA-STP)
2. Purchase price plus freight plus sales tax adjusted to 1972 dollars using the U.S. Department of Commerce Wholesale Price Index (WPI) for industrial commodities excluding farm products and foods
3. The sum of all reported capital costs adjusted to 1972 dollars using the EPA-STP Index
4. Operating labor expense

Table II-8. Distribution of operating package plants visited by size and type of treatment process.

Plant size, gpd	Number of plants	Type of process: Extended aeration	Type of process: Contact stabilization
600	1	1	
4,000	2	2	
9,000	1	1	
10,500	2	2	
13,000	1	1	
13,500	1	1	
15,000	3	3	
16,000	1	1	
20,000	1	1	
22,500	1	1	
25,000	4	3	1
30,000	1		1
31,000	1	1	
32,000	1	1	
35,000	2	2	
40,000	1		1
45,000	1	1	
70,000	1		1
75,000	1		1
76,000	1	1	
100,000	1		1
150,000	1		1
250,000	1		1
350,000	1		1
500,000	2		2
Total	34	23	11

5. Operating power expense

6. Maintenance expense

7. Total reported operating expenses.

Total reported capital costs include: purchase price plus freight plus sales tax; site preparation; plant installation and connection to power and to wastewater influent and effluent lines; other electrical work; start up; landscaping and yardwork; administrative building, laboratory, garage, and maintenance equipment; engineering and design; and administrative costs associated with the design, installation and startup of the plant. Total reported operating expenses include: labor; testing; power; wasting sludge; maintenance; housekeeping and yardwork; administration; and miscellaneous operating expenses.

The capital cost data collected are in dollars expended at the time of acquisition of the plant. Since these plants were acquired in various years, capital costs were converted to 1972 dollars to obtain comparable figures. Cost indexes were used to convert dollars actually paid to equivalent 1972 dollars. The quantity and quality of data did not warrant using different cost indexes for each subitem. Two different sets of costs indexes were used: EPA-STP[28,29] and WPI[30]. The WPI Index is perhaps a better index for converting the cost of manufacturing the package plant to 1972 dollars since a package plant is a manufactured product. The EPA-STP Index is vaoid for conventional, municipal sewage treatment plants constructed at the plant location. This latter index is perhaps more appropriate for many subitems, such as site preparation, installing and connecting to sewer pipes and power supply, etc., than is the WPI. The application of either index to any one of the subitems or any aggregation of the subitems is not entirely correct since none of the subitems, nor the aggregation of the subitems, are composed of the same balance of materials and services used in calculating the indexes.

Table II-9 and Figs. II-15-17 show the results of the regression analyses of the data from the operating plants.

Each line on each figure represents a separate, independent regression analysis. The characteristics of the plants included in a regression analysis is specified by the short verbal description along the side of the plotted line. If a class variable is not mentioned, then no distinction is made between plants on the basis of that class variable. For example, on Fig. II-16 the line labeled "total operating expenses; testing performed" represents a regression analysis of the total operating costs of all operating plants that performed testing and reporting activities, regardless of type of treatment process.

Also on Fig. II-16, the line labeled "total operating expenses; all plants" represents the regression analysis of the total operating costs of all operating plants regardless of the type of treatment plant and regardless of whether they performed testing and reporting activities.

The number of observations in the total capital cost analysis is greater than the number in the purchase price analysis because some package plant owners gave only total capital costs.

Total operating costs do not include costs of major replacements. Since the quantity and type of operating cost data obtained varied considerably, the total operating costs of a plant was included in the data subset only if the costs of labor and of power were given; otherwise, the total operating cost of a particular plant was excluded from this data subset.

Table II-9. Regression analysis information for data from operating package plants.

[a]Type of cost	[b]Cost index	[c]Type of treatment process	Testing and reporting	Number of observations in data set	Smallest plant in data set (100's of gpd)	Largest plant in data set (100's of gpd)	Log A	A	B	r^2
Total cap.	WPC-STP	—	—	29	6	5000	2.85730	719.95	0.62975	0.76
Purch. price	WPC-STP	—	—	20	6	5000	2.74392	554.52	0.63765	0.87
Purch. price	WPI	—	—	20	6	5000	2.67755	475.93	0.63868	0.89
Purch. price	WPC-STP	Extended a.	—	13	6	760	2.61274	409.94	0.68698	0.91
Purch. price	WPI	Extended a.	—	13	6	760	2.55204	356.42	0.68623	0.91
Total op.	—	—	—	23	40	5000	1.93825	86.746	0.62921	0.69
Total op.	—	Contact s.	—	10	250	5000	1.94743	88.600	0.64102	0.74
Total op.	—	—	Yes	15	40	5000	2.23352	171.21	0.54619	0.69
Total op.	—	—	No	8	135	760	1.43070	26.959	0.78973	0.60
Power	—	—	—	29	6	5000	1.12543	13.348	0.70475	0.68
Labor	—	Contact s.	—	10	250	5000	2.11130	129.21	0.49991	0.66
Power	—	Contact s.	—	11	250	5000	0.61097	4.0829	0.86439	0.88
Power	—	—	Yes	17	40	5000	1.17255	14.878	0.69216	0.88

[a]Total cap. = total capital costs
Purch. price = purchase price + freight + sales tax
Total op. = total operating expenses

[b]EPA-STP = Environmental Protection Agency — Sewage Treatment Plant Index
WPI = Wholesale Price Index

[c]Extended a. = extended aeration treatment process
Contact s. = contact stabilization treatment process

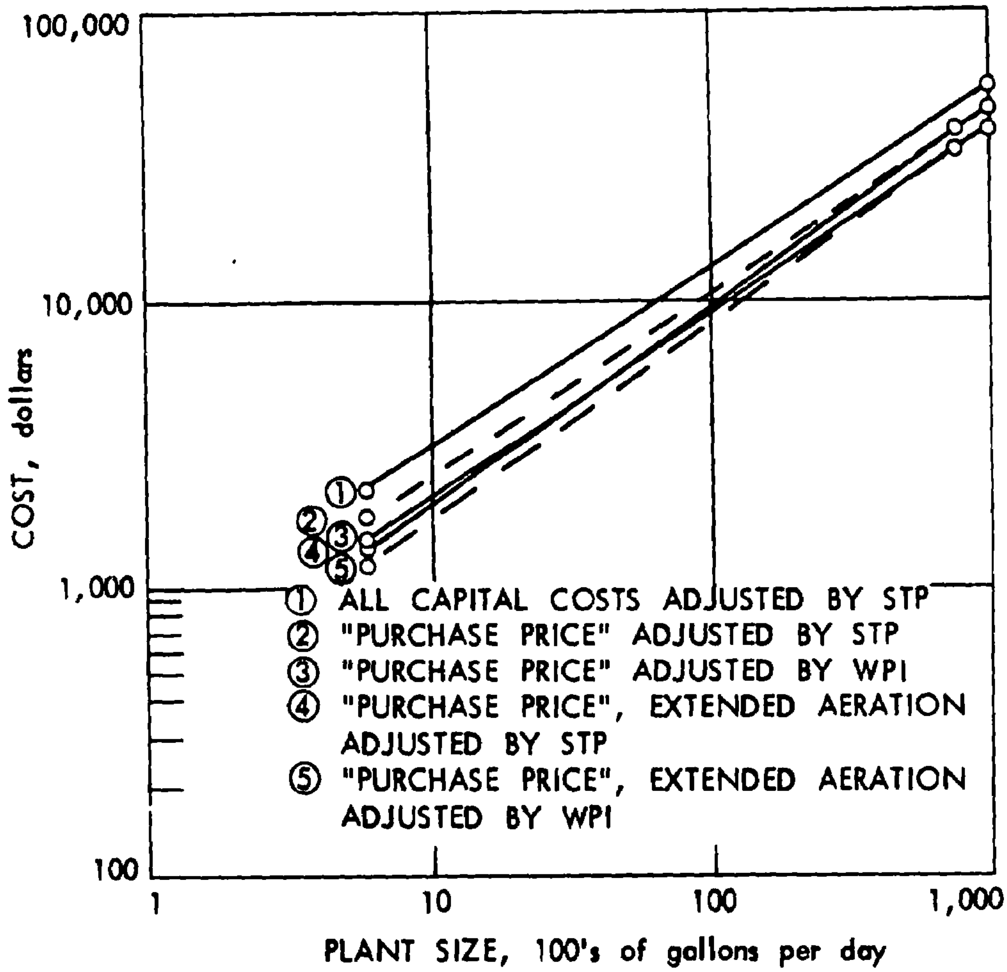


Fig. II-15. Regression lines for capital cost and for purchase price (plus freight plus sales tax) based on data from operating plants.

Separate regression analyses of labor costs and power costs were performed since there were a sufficient number of data points and the results are reported because the correlation coefficients were approximately 0.5 or higher. Regression analyses were performed on some other subdivisions of operating costs (such as sludge disposal) but are not reported since the correlation coefficients were quite low.

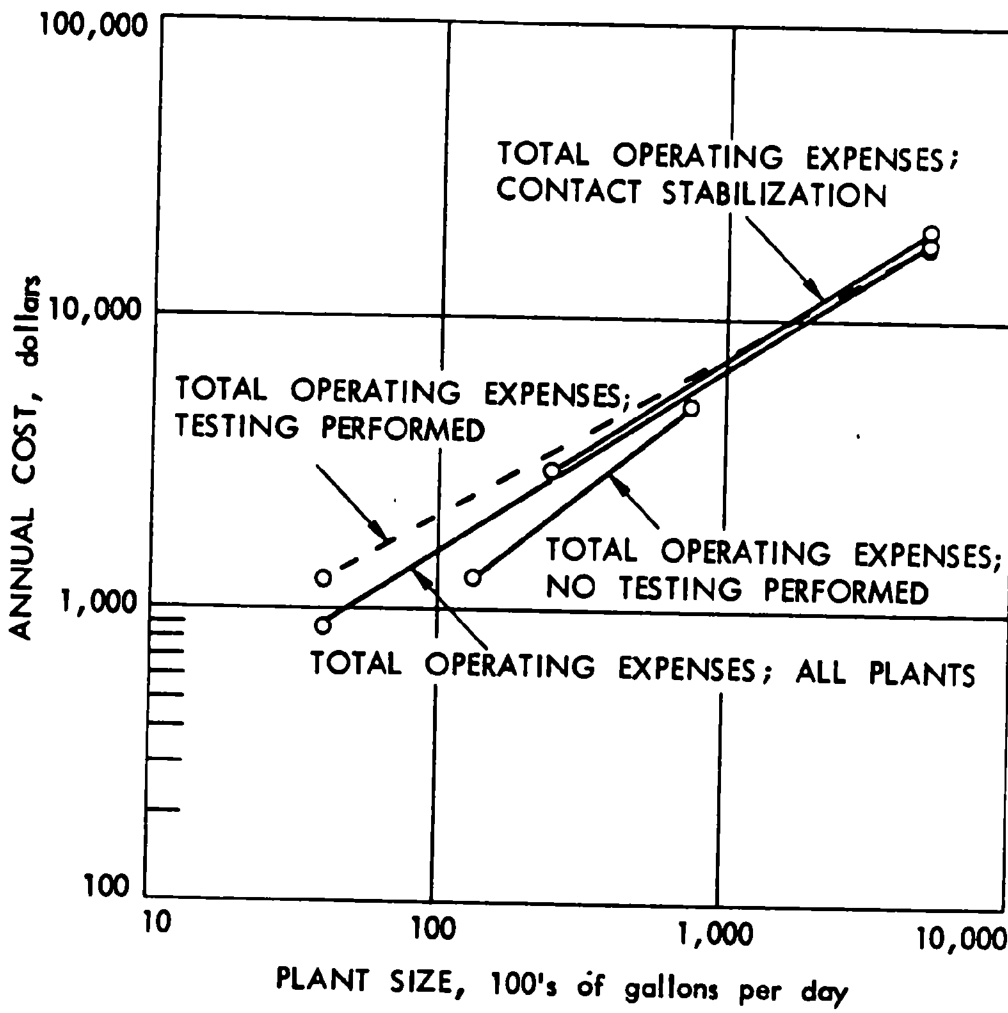


Fig. II-16. Regression lines for total annual operating expenses based on data from operating package plants.

3.4 Summary

The cost data from the operating plants was sketchy and incomplete at times and not infrequently was based on estimates by the operator and/or owner rather than accounting records. With few exceptions, the data from the operating plants did not yield high correlation coefficients (r^2). The notable exceptions are the "purchase price plus freight plus sales tax" data. Power costs also yielded high correlation coefficients.

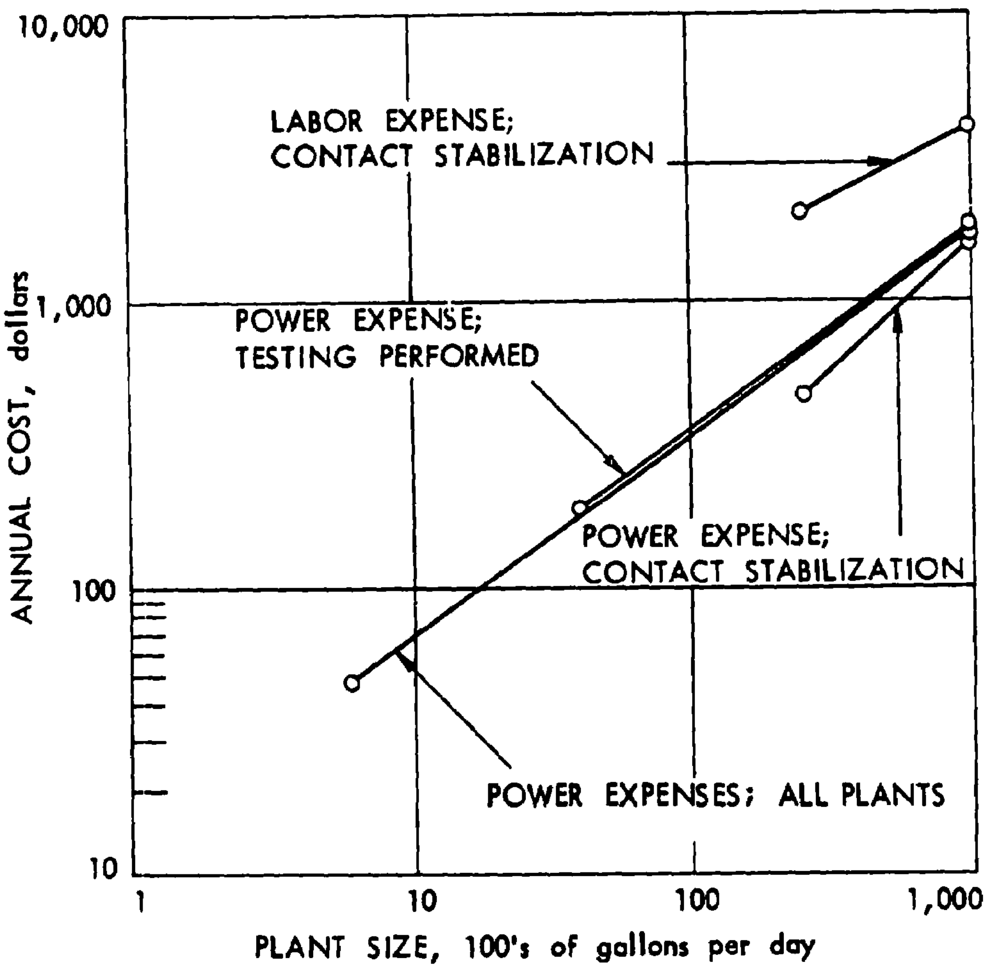


Fig. II-17. Regression lines for annual power expense and labor expense based on data from operating package plants.

The regression equations and graphs for total operating costs, especially, should be considered as relatively rough guidelines in estimating costs and should probably be considered as an estimate of minimum operating costs.

4. ESTIMATION OF PROBABLE AVERAGE SERVICE LIFE

4.1 Introduction

The probable service life of an item of property is the time from the date of installation to the date it will probably be retired from service. The probable average service life of a group of similar units is the average of the probable service lives of the individual units. Both probable service life and probable average service life are estimates since each is a forecast of what will happen rather than what has happened.

The causes of retirement of property may be classified as: (physical) deterioration, casualty, obsolescence, inadequacy, requirements of public authorities, and policy of management[31]. Physical deterioration is one of the lesser causes of retirement[31]. The other causes of retirement tend to reduce the life of a property to less than its physical life. Inadequate maintenance would also tend to reduce the life of a property.

Relevant information for estimating the probable average service life of a property group would include a life analysis of the past retirement characteristics of "identical" or similar property, analysis of technological progress, analyses of operating conditions, and a consideration of pertinent policies and decisions of owners and of governmental bodies.

Two common ways of describing the retirement characteristics of a group of property are by life tables and by survivor curves. A life table is a table of the number or percent surviving (or expected to be surviving) at successive ages over the life of the property in the group.

A survivor curve is a graph of the amount of property surviving (or expected to be surviving) at successive ages over the life of the property in the group.

The Iowa type curves are a well-known set of survivor curves[23,31,32] and will be used for illustrative purposes. The retirement characteristics of property can be completely described by specifying a probable average service life and a survivor curve (Fig. II-18). An R_5 curve is representative of property the units of which essentially all stay in service until near the probable average service life and then all retire in a relatively short period of time.

On the other hand, an O_4 type curve is representative of property, some units of which are retired shortly after the date of installation while other units continue in service for a relatively long period of time after the probable average service life. An S_3 type curve falls in between the R_5 and O_4 type curves. Although these curves are quite different in shape they represent property groups having the same probable average service life and they illustrate the concept that "identical" or similar items of property are not all removed from service at the same age but are retired over a period of time.

4.2 Data Available

Very little field data on package plant service lives were obtained. A number of manufacturers provided estimates, noting that actual data were generally not available and, therefore, the estimate was based primarily on judgment. The absence of actual data is due in part to the relatively short period of time that package plants (as defined for

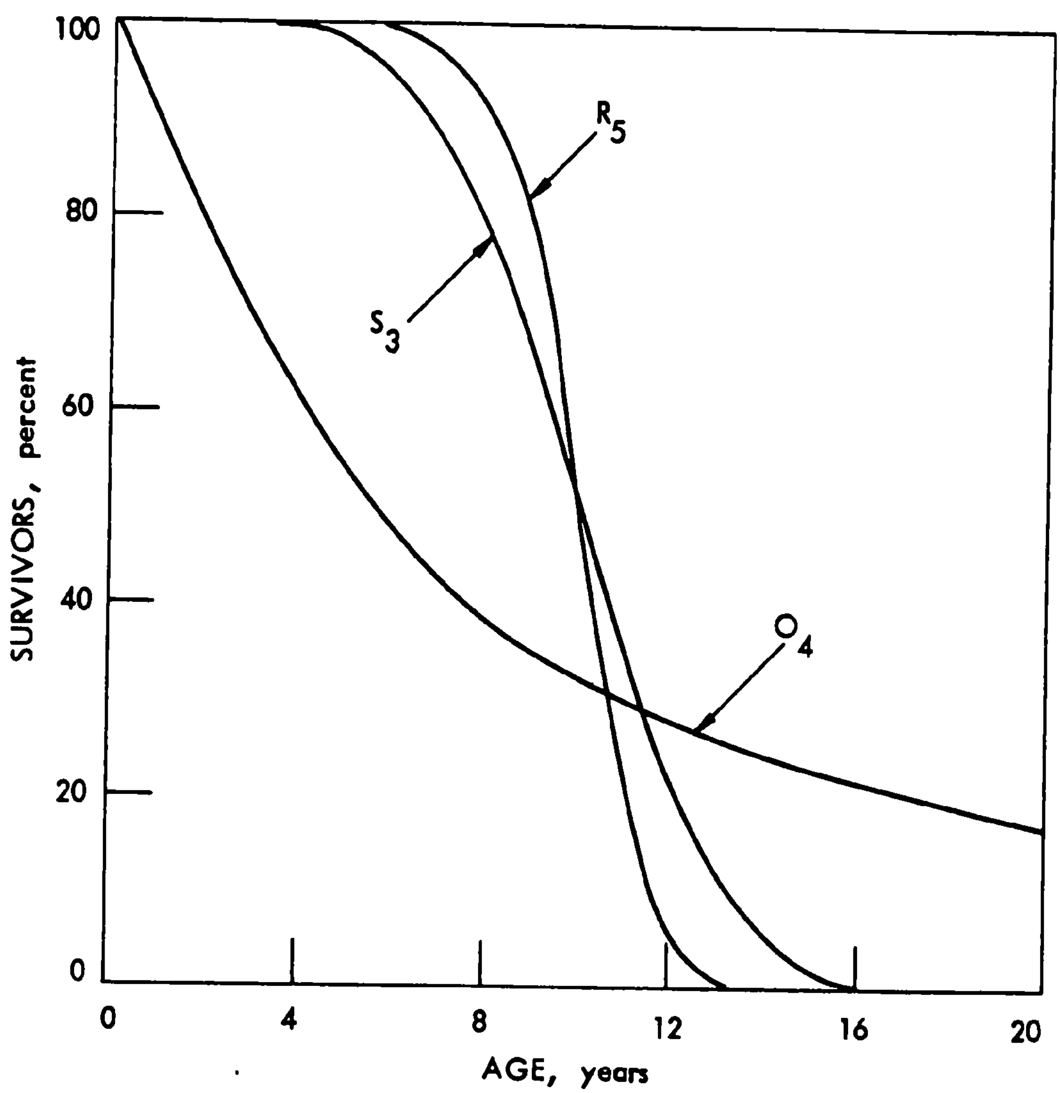


Fig. II-18. Iowa type survivor curves O_4, S_3, and R_5.

this report) have been in service. Also, no one owner owns a large number of package plants, so life analysis studies are not likely to be made by any particular owner.

Table II-9 is a summary of the data from manufacturers. The mode is the value occurring most frequently and the range is the lowest and the highest estimates received. Only two estimates of the probable average services life of concrete tanks were received, hence, there is no mode.

The number of estimates of the probable average service life received from manufacturers were: nine for steel tanks, two for precast concrete, nine for mechanical equipment, and four for fiberglass and plastic tanks.

Some data on the replacement of motors and blowers were obtained from the operating plants visited during the study. Life tables for motors and blowers, Table II-10, were constructed based on all of the information available from these operating plants (i.e., all motors were included in one group regardless of size, type, etc.). The life tables were calculated by the retirement rate method[31,33] using a placement band of 1962-1971 and an expanding observation band starting with the single year 1971 and ending with the band 1962-1971[33]. The corresponding survivor curves for motors and blowers are shown in Fig. II-19. The percent surviving at ages 3-1/2 and later are based on very few data points; hence the usefulness of the life tables and survivor curves as guides for predicting the future are marginal.

Table II-10. Manufacturers' estimates of the probable average service life of package plants.

	Mode (years)	Range (years)
Steel tanks	20	10-40
Precast concrete tanks	–	20-50
Fiberglass or plastic tanks	50	15-50
Mechanical equipment	10	3-35

Table II-11. Life tables for motors and blowers.

Age, yr	Motors, % surviving	Blowers, % surviving
0	100.0	100.0
1/2	91.7	91.7
1-1/2	91.7	83.4
2-1/2	91.7	83.4
3-1/2	91.7	83.4
4-1/2	91.7	83.4
5-1/2	91.7	83.4
6-1/2	91.7	83.4
7-1/2	91.7	83.4
8-1/2	91.7	41.7
9-1/2	91.7	41.7

The Asset Depreciation Range System of the Department of the Treasury[34] does not set an asset guideline period for wastewater treatment plants but it does set an asset guideline period of 50 years for the depreciation property of water utilities used in the gathering, treatment, and commercial distribution of water.

4.3 Conclusions

Insufficient data are available to make a vaoid estimate of the probable average service life of either mechanical equipment or basins of package plants. What data are available are not inconsistent with the estimates made by the manufacturers.

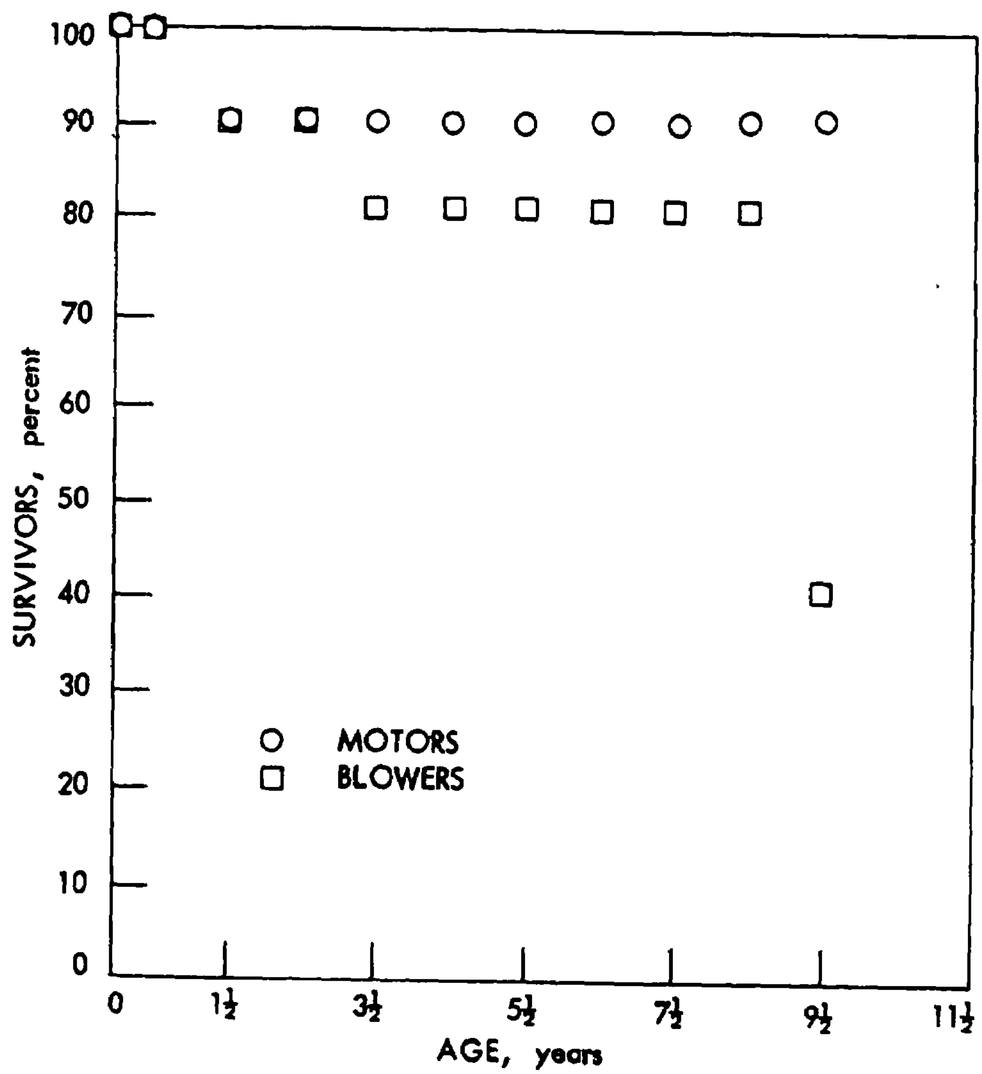


Fig. II-19. Survivor curves for motors and blowers.

Similarly, insufficient data are available to estimate the retirement pattern or survivor curve for motors, blowers, or basins. Since not all items of a given type will last exactly the same number of years, a middle of the road approach, such as an S_3 Iowa type curve, rather than an R_5 or O_4 survivor curve would seem appropriate (Fig. II-18).

The data and comments received from package plant manufacturers seem to indicate that with proper maintenance and repair, motors may physically last for a considerable length of time, perhaps as long as 30 years or so, whereas blowers or compressors may have a physical life of approximately 10 years.

The physical life of steel tanks is quite dependent upon proper installation and maintenance, including replacement of the magnesium anodes when necessary. With reasonable care, the physical life of steel tanks may approach 40 years or more.

With proper installation and maintenance, precast concrete tanks, plastic and fiberglass tanks should physically last an indefinite period of time; hence, a physical life of 50 years or more does not seem unreasonable.

Based solely on the manufacturers' estimates and comments and preceding considerations, one might consider the following as maximum lives with the probably average service lives being somewhat less, perhaps as much as 50% less: 40 years or more for steel tanks; 50 years or more for precast concrete, fiberglass, and plastic tanks; approximately 30 years for motors; and 10 or more years for blowers or compressors. The probable average service life is less than the maximum physical life for two reasons (1) not all units will physically attain the maximum physical life for a particular type of property for a variety of reasons, including a lack of proper maintenance and (2) property is frequently retired earlier than physical life for various causes such as obsolescence, inadequacy, and requirements of public authorities.

The Office of Industrial Economics of the Department of the Treasury, created in 1971, includes among its duties the collection of data from tax returns and other sources to update the asset guideline class lives of the Asset Depreciation Range (ADR) System. Such data may provide a basis for a future study of the probable average service life of package wastewater treatment plants.

5. REFERENCES

1. Smith, R. "Cost of Conventional and Advanced Treatment of Wastewater." Journal of the Water Pollution Control Federation, 40, 1546-1559. 1968.

2. Michel, Robert L., and Johnson, Walter W. Costs and Man-Hours for Operation and Maintenance of Municipal Wastewater Treatment Plants — 1957-1970. Preliminary Draft. U.S. Department of the Interior, Federal Water Quality Administration, Construction Grants and Engineering Branch, Division of State and Local Programs. Washington, D.C. October 1970.

3. Michel, Robert L. Construction Costs of Municipal Wastewater Treatment Plants (1967-1969). Preliminary Draft. U.S. Department of the Interior, Federal Water Quality Administration, Construction Grants and Engineering Branch, Division of State and Local Programs. Washington, D.C. May 1970.

4. Michel, Robert L. "Cost and Manpower for Municipal Wastewater Treatment Plant Operation and Maintenance 1965-1968." Journal of the Water Pollution Control Federation, 42, 1883. November 1970.

5. Drews, R. J. L. C., Malan, W. M., Merring, P. G. J., and Moffatt, B. "The Orbol Extended Aeration Activated Sludge Plant." Journal Water Pollution Control Federation, 44, 2, 221-231. February 1972.

6. Black and Veatch Consulting Engineers. Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities. Cincinnati, Ohio, Environmental Protection Agency, Water Quality Office, Advanced Waste Treatment Research Laboratory. 1971.

7. Goodman, Brian L. Package Sewage Treatment Plant Criteria Development, Part I: Extended Aeration. National Sanitation Foundation Report of FWPCA Demonstration Grant Project, WPD-74. Ann Arbor, Michigan, National Sanitation Foundation. September 1966.

8. Dempster, Andrew T. Package Sewage Treatment Plant Criteria Development, Part II: Contact Stabilization. National Sanitation Foundation Report of FWPCA Demonstration Grant Project, WPD-74. Ann Arbor, Michigan, National Sanitation Foundation. June 1968.

9. National Sanitation Foundation. NSF Joint Committee on Special Processes or Devices Used in Treating Wastewater. Standard No. 40 Relating to Individual Aerobic Wastewater Treatment Plants. P.O. Box 1468, Ann Arbor, Michigan. The National Sanitation Foundation. November 13, 1970.

10. National Sanitation Foundation, NSF Joint Committee on Special Processes or Devices Used in Treatment Wastewater. Basic Criteria C-9, Relating to Evaluation of Special Processes or Devices Used in Treating Wastewater. P.O. Box 1468, Ann Arbor, Michigan. The National Sanitation Foundation. November 13, 1970. (Unavailable for public distribution.)

11. Drobny, Neil L., and Qasim, Syed R. Analysis of Wastewater Treatment and Disposal Systems for Advanced Bases. Report by Battelle Memorial Institute to U.S. Naval Civil Engineering Laboratory, Port Hueneme, California (Contract No. N62399-69-C-0036; CR 70.011). October 1969. (Available from Commission on Rural Water, 221 N. LaSalle Street, Chicago, Ill. 60601.)

12. Qasim, S. R., Drobny, N. L., and Valentine, B. W. "Waste Management Systems for Advanced Military Bases." Water and Sewage Works, 118, R-92 to R-100. August 31, 1971.

13. Snoeyink, V. L., and Mahoney, J. A. Summary of Commercially Available Wastewater Treatment Plants. Technical Report No. AFWL-TR-72-45. Air Force Systems Command, Air Force Weapons Laboratory, Kirtland AFB, New Mexico. NTIS Number AD-747032. July 1972.

14. Goldstein, Steven N. Technical Manual on Wastewater Treatment Systems for Rural Communities. Washington, D.C., Mitre Corporation, Publication No. MTR 6223. August 1972.

15. Goldstein, Steven. Wastewater Treatment Systems for Rural Communities. Washington, D.C., Commission on Rural Water. 1973.

16. Bailey, J., and Wallman, H. A Survey of Household Waste Treatment Systems. Journal of the Water Pollution Control Federation, 44, 2349-2360. December 1971.

17. Seymour, Gerald G. Operation and Performance of Package Treatment Plants. Journal of the Water Pollution Control Federation, 44, 2, 274-292. February 1972.

18. Dague, Richard R., Elbert, Gary F., and Rockwell, M. Daniel. Contact Stabilization in Small Package Plants. Journal of the Water Pollution Control Federation, 44, 255-264. February 1972.

19. Kugelman, I. J., Schwartz, W. A., and Cohen, J. M., "Advanced Waste Treatment Plants for Treatment of Small Waste Flows." Advanced Waste Treatment and Water Reuse Symposium, Session Four, January 12-14, 1971, Dallas, Texas.

20. Mulbarger, M. C. "Nitrification and Denitrification in Activated Sludge Systems." Journal of the Water Pollution Control Federation, 43, 10, 2059-2070. October 1971.

21. Reid, Leroy C., Jr. Design of Wastewater Disposal Systems for Individual Dwellings. Journal of the Water Pollution Control Federation, 43, 10, 2004-2010. October 1971.

22. University of Wisconsin. Small Scale Waste Management Project. Progress Report. University of Wisconsin, Madison, Wisconsin. October 1972.

23. Smith, Gerald W. Engineering Economy: Analysis of Capital Expenditures. Ames, Iowa, The Iowa State University Press. 1968.

24. Krebs, Robert. Private communication. Multi-Flow, Inc., 500 Webster Street, Dayton, Ohio. 1972.

25. Beatty, Marvin T., and Quigley, John T. Waste Disposal Demonstration Project — Progress Report July 1 to December 31, 1971. Madison, Wisconsin, School of Natural Resources, University of Wisconsin. December 31, 1971.

26. DiGregorio, David. Cost of Wastewater Treatment Processes. Cincinnati, Ohio. U.S. Department of the Interior, Federal Water Pollution Control Administration, The Advanced Waste Treatment Research Laboratory, Robert A. Taft Water Research Center. December 1968.

27. Smith, R., and Eilers, R. G. Cost to the Consumer for Collection and Treatment of Wastewater. Water Pollution Control Research Series #17090. Washington, D.C., Superintendent of Documents, U.S. Government Printing Office. July 1970.

28. Environmental Protection Agency. Water Quality Office. Sewerage Construction Cost Indexes in 20 Cities. Engineering News — Record, 188, 25, 96. June 22, 1972.

29. U.S. Department of the Interior. Federal Water Pollution Control Administration. Sewer and Sewage Treatment Plant Construction Cost Index. Washington, D.C., Superintendent of Documents, U.S. Government Printing Office. December 1967.

30. U.S. Department of Commerce. Bureau of the Census. Pocket data book. Washington, D.C., 207, Table 287.

31. National Association of Regulatory Utility Commissioners. Depreciation Subcommittee of the Committee on Engineering, Depreciation, and Valuation. Public utility depreciation practices. 33 27 ICC Building, P.O. Box 684, Washington, D.C. National Association of Regulatory Utility Commissioners. 1968.

32. Pollock, Richard L. Tax Depreciation and the Need for the Reserve Ratio Test. Tax Policy Research Study Number Two. Washington, D.C. The Department of the Treasury. 1968.

33. Winfrey, Robley. Statistical Analysis of Industrial Property Retirements: revised April 1967 by Harold A. Cowles, Professor, Department of Industrial Engineering. Ames, Iowa, Iowa State University of Science and Technology, Engineering Research Institute Bulletin 125, revised edition. 1967.

34. U.S. Department of the Treasury. Asset Depreciation Range (ADR) System, Washington, D.C. U.S. Department of the Treasury. 1971.

APPENDIX II-A. List of package plants that have been evaluated or are under evaluation by the National Sanitation Foundation

Certificate of performance for an extended aeration package sewage treatment plant issued by the National Sanitation Foundation

under the provisions of the Standard Performance Evaluation Method*

	Manufacturer	Plant designation	Rated capacity	Date certified
1.	Can-Tex Industries P.O. Box 340 Mineral Wells, Texas 76076	75M75 Tex-A-Robic[R] SN No. 554	7,500 gpd	November 1967
2.	FMC Corporation Environmental Equipment Division 2240 West Diversey Avenue Chicago, Illinois 60647	Chicago Pump Rated Aeration Medium Steel SL-118-B Model No. SA 4405	9,000 gpd	November 1967
3.	Davco Division Davis Water & Waste Industries P.O. Box 1419 Thomasville, Ga. 31792	Series DA, Model 9D10SC	10,000 gpd	November 1967
4.	Defiance Company P.O. Drawer 186 Tallevast, Florida 33588	Defiance Sewage Treatment Plant, Model 10	10,000 gpd	November 1967
5.	Mack Industries, Inc. P.O. Box 335 Valley City, Ohio 44280	Model MV-5000	5,000 gpd	November 1967
6.	Smith and Loveless Division Ecodyne Corporation 14040 West Santa Fe Trail Lenexa, Kansas 66215	Cylindrical Oxigest Treatment Plant Model 5CY2	2,000 gpd	November 1967

	Manufacturer	Plant designation	Rated capacity	Date certified
7.	Water Pollution Control Corp. P.O. Box 744 Milwaukee, Wisconsin 53201	Model Mark IV, No. 9	16,000 gpd	November 1967
8.	Clow Corporation P.O. Box 324 Florence, Kentucky 41042	Aer-O-Flo Model S-50-33-2	5,000 gpd	November 1967
9.	Lyco-Z F, Inc. P.O. Box 281 Englishtown, N.J. 07726	Model 530-8	6,000 gpd	November 1968
10.	Marolf Hygienic Equipment, Inc. 7337 Sylvania Avenue Toledo, Ohio 43623	Precast Concrete Series Model 1-7.5	7,500 gpd	November 1968
11.	Pall Corporation 30 Seacliff Avenue Glen Cove, New York 11542	Model No. EA 100C	10,000 gpd	November 1968
12.	Pollution Control, Inc. Lunken Airport Admin. Bldg. Cincinnati, Ohio 45226	Activator Model S-6	6,000 gpd	November 1968
13.	World Ecolog Systems Co. P.O. Box 311 Geneva, New York 14456	Model No. EA 100C	10,000 gpd	November 1968
14.	Jet Aeration Company 750 Alpha Drive Cleveland, Ohio 44143	Model No. JCP-25	2,500 gpd	November 1970

	Manufacturer	Plant designation	Rated capacity	Date certified
15.	Topco Company Sterling-Salem Corporation P.O. Box 507 Salem, Ohio 44460	AD-50-Topco Sewage	5,000 gpd	November 1970
16.	BiO$_2$ Systems, Inc. 3306 Wyoming Kansas City, Missouri 64111	Sani-Cell Model 600	600 gpd	November 1970
17.	Purestream Industries, Inc. 1450 Dixie Highway Covington, Kentucky 41011	Model P-t-2	5,000 gpd	June 1972
18.	Norweco, Inc. 189 Woodlawn Avenue P.O. Box 521 Norwalk, Ohio 44857	Model ST-30	3,000 gpd	December 1972

*Package sewage treatment plant criteria development — Part I: Extended aeration (September 1966).

Product listing for special processes or devices used in treating wastewater issued by the National Sanitation Foundation

under the provisions of NSF basic criteria C-9

Manufacturer	Plant designation	Rated capacity	Date
1. Pollutrol Technology, Inc. P.O. Box 3727 Portland, Maine 04104	Puritrol Process Model 3M (Seal No. 8064)	3,000 gpd	November 1972

Note: Tested PURITROL MODEL 3M (3,000 gpd) "batch processing" extended aeration.

Product listing for individual aerobic wastewater treatment plants
issued by the National Sanitation Foundation

under the provisions of NSF Standard No. 40

	Manufacturer	Plant designation	Rated capacity	Classification	Seal No.
1.	Flygt Corporation	Mini-Plant			8058
	129 Glover Avenue	Model 4291-4	400 gpd	II	
	P.O. Box 857	Model 4291-6	600 gpd	II	
	Norwalk, Connecticut 06856				
2.	Nayadic Sciences, Inc.	Nayadic			8063
	Village of Eagle	Model M-6A	600 gpd	II	
	Uwchland, Pennsylvania 19480	Model M-1050A	1,050 gpd	II	

Note: Tested Flygt 4291-4 and Nayadic M-6A.

Package wastewater treatment plants

under performance evaluation at National Sanitation Foundation
Jan. 15, 1973

	Manufacturer	Plant designation	Rated capacity	Evaluation criteria
1.	General Environmental Equipment, Inc. 5020 Stepp Avenue Jacksonville, Florida 32216	Model #G-15 EA	15,000 gpd	Extended aeration (to start April 1973)
2.	The Aquatair Corporation 111 West First Street Dayton, Ohio 45402	Model P50PE	5,000 gpd	NSF Basic Criteria C-9
3.	Bio-Pure, Inc. 27th & Main Streets Boise, Idaho 83707	Model BP-30	3,000 gpd	NSF Basic Criteria C-9
4.	Cromaglass Corporation P.O. Box 1146 Williamsport, Pa. 17701	CA-900	400 gpd	NSF Standard No. 40
5.	Marubeni-America Corp. 200 Park Avenue New York, N.Y. 10017	Hi-Bakkie Model M-320	600 gpd	NSF Standard No. 40
6.	Multi-Flo, Inc. 500 Webster Street Dayton, Ohio 45401	Multi-Flo FT-0.5	500 gpd	NSF Standard No. 40

APPENDIX II-B. Bibliography of cost and/or evaluation studies of package plants

Azad, H. S., and Hayden, P. L., "Activated Sludge." J. Water Pollution Control Federation, 44, 925 (June 1972).

Bailey, James R.; Benoit, Richard J.; Dodson, John L.; Robb, James M.; and Wallman, Harold, "A Study of Flow Reduction and Treatment of Wastewater from Households." Washington, D.C., Superintendent of Documents, U.S. Government Printing Office (1969).

Baker, Ralph H., "Current Use of Small Activated Sludge Plants in Florida," presented at Water Pollution Control Federation Convention, Bal Harbour (September 1964) in manuscript.

Baker, Ralph H., "Package Aeration Plants in Florida." J. Sanitary Engineering Division, Proc. American Society of Civil Engineers, 88, SA 6: pp. 75-95 (November 1962).

Baker, Ralph, "Package Aeration Plants in Florida." J. Sanitary Engineering Division, Proc. American Society of Civil Engineers, 89, SA 6: pp. 49-52 (December 1963).

Banks, D. H., and Gower, B. J., "The Lubeck Activated-Sludge Plant at Ticehurst Sewage-Treatment Works of Battle RDC." Water Pollution Control, pp. 92-97 (1972).

Benjes, Henry H., Jr., and McKinney, Ross E., "Specifying and Evaluating Aeration Equipment." J. Sanitary Engineering Division, ASCE, 93: SA 6, 55-64 (1967).

Bergles, Joseph L., and Nelson, Marvin A., "Waste Disposal and Independent Research Progress Report." Ber-Nel Sewage Treatment Plant, Division of Nelson Septic Tank Co., Route 1, Box 169, Union Grove, Wisc. 53182 (July 31, 1972).

Bernhart, A. P., "Waste Water Units for Individual Buildings and Houses," Engineering Journal, 47: 7, 19-25 (July 1964).

Besik, F., "Waste Water Reclamation in a Closed System." Water and Sewage Works, 118: 7, 213 (July 1971).

Black, S. A., "High-Rate, Combined-Tank Activated-Sludge Process Evaluated." Water and Pollution Control, Co. 105, pp. 42-44 (October 1967).

Bloodgood, D. E., "Waste Treatment for an Individual Home with Reuse of the Water." Purdue University, School of Civil Engineering, Lafayette, Ind. 47907.

Bodien, D. G., and Stenburg, R. L., "Microstraining Effectively Polishes Activated Sludge Effluent," Water and Wastes Engineering, 3: 9, 74-77 (September 1966).

Boyko, B. I., "Mixing Studies on a Full Scale Aeration Tank." Ontario Water Research Commission Research Publication 19 (December 1968).

Bradley, R. M., and Isaac, P. C. G., "The Cost of Sewage Treatment." Water Pollution Control, 68: 4, 368-402 (1969).

Burton, F. L.; Theisen, H. M.; and Snveyinl, V. L., "Water Treatment Costs for the Small Plant." Industrial Water Engineering, 6: 3, 24-26 (March 1969).

Butts, Thomas A., and Evans, R. L., "Cost of Municipal Sewage Treatment Plants in Illinois." Illinois Water Survey. Urbana Circular No. 99, 39 pages (1970).

Campbell, L. A., and Smith, D. K., "An Investigation of Individual Household Aerobic Sewage Treatment Units," Canadian Municipal Utilities (November-December 1963).

Clark and Groff Engineers, "Sanitary Waste Disposal for Navy Camps in Polar Regions." Contract NBy-32205, Salem, Ore. (May 1962).

"Costs of Modern Sewage Treatment Plants." Public Works, 96: 1, 79-82 (January 1965).

Cromaglass Corporation. Performance data. Williamsport, Pa. No date. (Data taken during 1967-8-9.)

Culp, G. L., and Hansen, S. P., "Extended Aeration Effluent Polishing by Mixed-Media Filtration." J. Water and Sewage Works, 114, 46-51 (February 1967).

Dart, M. C., and Spurr, T., "Treatment of Domestic Sewage by the Contact Stabilization Process." Water and Waste Treatment Journal (Brit.), 12: 1, 12 (1968).

Downing, Paul B., "The Economics of Urban Sewage Disposal." New York, Frederick A. Praeger, Publishers (1969).

Dryden, F. E., et al., "High Rate Activated Sludge Treatment of Fine Chemical Wastes." Sewage and Industrial Wastes, 28: 2, 183-194 (February 1956).

Edward C. Hess Associates, Consulting Civil Engineers. Proposed operation, data collection, sampling and analytical methods to evaluate performance and test results and conclusions. Environmental Services, Inc., Granite and West Streets, Midland Park, N.J. 07432 (December 15, 1969).

"Evaluation of Activated Sludge Treatment Plants Performance," Symposium Harvard (August 1971).

Evans, D. R., and Wilson, J. C., "Capital and Operating Costs — AWT," J. Water Pollution Control Federation, 44: 1, 1-13 (January 1972).

Eye, J. David; Eastwood, David P.; Requena, Fernando; and Spath, David P., "Field Evaluation of the Performance of Extended Aeration Plants." Journal Water Pollution Control Federation, 41, 1299-1318.

FMC Corporation, Central Engineering Laboratories, "Complete-Mixing-Operating Parameter Studies — Waste Treatment Plant," P.O. Box 580, Santa Clara, Calif. (June 1967).

Goldstein, Steven N., "Community Sewerage Systems Versus On-Site Sewage Treatment Systems." A paper presented at the Ohio Home Sewage Disposal Conference. Fawcett Center for Tomorrow, Ohio State University, Columbus, Ohio (January 29, 1973).

Goldstein, S. N., and Wenk, V. D., "A Review of On-Site Domestic Sewage Treatment Processes and Systems Alternatives." The Mitre Corp., MIP-638 (January 1972).

Goldstein, S. N.; Wenk, V. D.; Fowler, M. C.; and Poh, S. S., "A Study of Selected Economics and Environmental Aspects of Individual Home Wastewater Treatment Systems." McLean, Virginia, Mitre Corp. Available from NITS as PB-209-962 (March 1972).

Grich, E. R., "Operating Experience with Activated Sludge Reaeration." J. Water Pollution Control Federation, 33: 8, 856-863 (August 1961).

Guiver, K., and Hardy, J. P., "Operational Experience with Extended Aeration Plants." Water Pollution Control, 67, 194-204 (1968).

Hammer, Mark C., and Tilsworth, Timothy, "Field Evaluation of a High Rate Activated Sludge System." Water and Sewage Works, pp. 261-266 (June 1968).

Herriot, A., "Sewage Treatment in Scotland: The Cost of the Service." Proc. Institute Sewage Purification, 2, 157 (1963).

Howe, Richard S., "Operational Problems of Package Activated Sludge Plants," J. Water Pollution Control Federation, 33: 11, 1166 (November 1961).

Howells, D. H., and Dubois, D. P., "Design Practices and Costs for Small Secondary Sewage Treatment Plants in the Upper Midwest." Sewage and Industrial Wastes, 30: 11, 1327-1335 (November 1958).

Hurwitz, E.; Nogaj, R. J.; and Roeber, J. A., "Performance of Surface Aerators under Widely Varying Loadings in an Activated Sludge System." Water and Sewage Works, Vol. 113, R-209, R-218 (November 30, 1965).

Jones, P. H., "Waste Water Treatment by Contact Stabilization of Penetanguishere, Ont." Water and Pollution Control, 106: 2: 34-35, 38-39, 43, 45, 34 (February 1968).

Kiker, J. E., Jr., "Package and Subdivision Sewage Treatment Plants." J. Water Pollution Control Federation, 32: 8, 878-885 (August 1960).

Koelin, J. R., "Apparatus for Sewage Treatment." Chemical Abstracts, 75, 9704 (1971).

Lamb, M. A.; Culp, G. L.; Morris, G. L.; Greiner, J. A.; and McKinney, R. E., "Package Aeration Plants in Florida." Discussion. J. Sanitary Engineering Division, Proc. American Society of Civil Engineers, 89, Sa3, 79-87 (1963).

Logan, J. A., "An Analysis of the Economics of Sewage Treatment." Unpublished report. Northwestern University Technological Institute (1962).

Logan, J. A.; Hatfield, W. D.; Russel, G. S.; and Lynn, W. R., "An Analysis of the Economics of Wastewater Treatment," J. Water Pollution Control Federation, 34, 860-882 (1962).

MacDonald, F. W., and Bastamante, R. B., "The Efficiency of Extended Aeration." Public Works, 97: 4, 88-89 (April 1966).

Massachusetts Health Research Institute, Inc., "A Study of Small, Complete Mixing, Extended Aeration, Activated Sludge Plants in Massachusetts." New England Interstate Water Pollution Control Commission — Boston (1961).

Mau, G. E., "Sewage Treatment Cost in Kansas." Sewage and Industrial Wastes, 30, 1143 (December 1958).

McKinney, R. E., "A Study of Small, Complete Mixing, Extended Aeration, Activated Sludge Plants in Massachusetts." New England Interstate Water Pollution Control Commission, Boston, Mass. (1961).

McKinney, R. E., and Schwinn, D., "Waste Treatment for an Ice Cream Plant and Restaurant." Public Works, 91: 4, 82 (1960).

Michel, R. L.; Pelmoter, A. L.; and Palange, R. C., "Operation and Maintenance of Municipal Waste Treatment Plants." J. Water Pollution Control Federation, 41, 335 (1969).

Middlebrooks, E. J., et al., "Kinetics and Effluent Quality in Extended Aeration." Water Resources, 3: 1, 39-46 (January 1969).

Nicoll, E. H., "Extended Aeration in British Package Plants." J. Water Pollution Control Federation, 43, 293-305 (February 1971).

Ohio Department of Health, "A Study of Aerobic Digestion Plants in Ohio 1959-1960." Ohio Department of Health, Columbus, Ohio (1960).

Ohio State University Engineering Experiment Station, "A 23-Month Study of Individual Household Aerobic Sewage Treatment Systems" (July 1961).

Perry, R. R., "Adoption of an Aerobic Sewage Treatment Process for Individual Homes." A thesis, Purdue University, Lafayette, Ind. (August 1951).

Pipes, W. O., "Activated Sludge." J. Water Pollution Control Federation, 41: 6, 908-915 (June 1969).

Porges, R., and Morris, G. L., "Extended Aeration Sewage Treatment, A Preliminary Evaluation." Publication of the U.S. Public Health Service, Robert A. Taft Sanitary Engineering Center (1960).

Porges, Ralph, and Morris, Grovel L., "Small Extended-Aeration Sewage Treatment Plants." J. Environmental Health, 25: 6 (May-June, 1963).

Porges, R.; Morris, G. L.; Towne, W. W.; Struzeski, E. J., Jr.; and Harlow, G. L., "Sewage Treatment by Extended Aeration." J. Water Pollution Control Federation, 33: 12, 1260-1266 (December 1961).

Rasmuson, J. A., and Setser, J. L., "Start Up and Operation of an Environmental/One Chemical – Biological Treatment Plant for Country Knolls Extension – Malta." 2773 Balltown Road, Schenectady, N.Y. (December 1972).

Rigby, L. E., "Aerobic Treatment of Sewage for Individual Homes and the Reuse of the Treated Waste Water for Toilet Flushing." A thesis, Purdue University, Lafayette, Ind. (January 1954).

Rowan, P. O.; Jenkins, K. H.; and Butler, D. W., "Sewage Treatment Construction Costs." J. Water Pollution Control Federation, 32: 6, 594 (June 1960).

Rowan, P. O., Jenkins, K. L., and Howells, D. H., "Estimating Sewage Treatment Plant Operation and Maintenance Costs." J. Water Pollution Control Federation, 33: 2, 111-121 (1961).

Sanitary Engineering Laboratories, Inc. Report of Operation of "Sitton-Air" Sanitation System. Sitton Manufacturer's Association, Inc. (November 25, 1968).

Schaller, C. L., et al., "Evaluation of a Proprietary Waste Treatment System Aboard the USCGC Alert (WMEC-630) Based at Cape May, N.J." U.S. National Technical Information Service. Government Reports Announcements, 71: part 3, 152 (July 10, 1971).

Smith, B. C., "The Use of Ultrafiltration Membranes for Activated Sludge Separation." Annual Industrial Waste Conference, Purdue University, pp. 1300 (May 7, 1969).

Thomas, Harold A.; Coulter, James B.; Bendixen, Thomas W.; and Edwards, Allan B., "Technology and Economics of Household Sewage Disposal Systems." J. Water Pollution Control Federation, 32: 2, 113-141 (February 1960).

Torpey, W. N., et al., "Rotating Disks with Biological Growths Prepare Wastewater for Disposal or Reuse." J. Water Pollution Control Federation, 43: 11, 2181-2188 (November 1971).

Towend, C. B., "The Economics of Wastewater Treatment." Proc. Institute of Civil Engineers, 15, 209-30 (March 1960).

U.S. Department of Health, Education and Welfare, Public Health Service, Division of Water Supply and Pollution Control, "Modern Sewage Treatment Plants — How Much Do They Cost?" Public Health Service Publication No. 1229. U.S. Government Printing Office, Washington, D.C. (1964).

Ward, John C. Letter report to the company. Pollution Control Devices, Inc., P.O. Box 31104, Aurora, Colo, 80010 (1969).

Water Technology Laboratory, Inc. Laboratory Reports on Canatraco FLPC Waste Treatment Pilot Installation in Beaconsfield, Quebec, Canada. Canatraco, Ltd., 5800 Cote St. Francois, St. Laurent, Montreal, Quebec, Canada (1972).

Watson, K. S., and Gagel, J. D., "Sanitary Wastewater Characteristics of Applicance Park and Package Plants." J. Water and Sewage Works, 113: 10, 391-397 (1966).

Wenk, V. D., "Water Pollution: Domestic Wastes." A Technology Assessment Methodology Study, Vol. 6, PB 202778-06, prepared for the Office of Science and Technology by the MITRE Corporation, MTR-6009 (June 1971).

APPENDIX II-C. Sample letter to manufacturers of package plants and sample letter to owners of package plants

LETTER TO MANUFACTURERS OF PACKAGE PLANTS

Department of Industrial Engineering
212 Marston Hall
Ames, Iowa 50010

IOWA STATE
UNIVERSITY

Telephone 515-294-1682

Dear Sir:

The Environmental Protection Agency, Office of Water Programs, Manpower Development Staff, has awarded a grant to the Industrial Engineering Department of Iowa State University for a project entitled, "Estimating Manpower Requirements and Selected Cost Factors for Small Wastewater Treatment Plants."

One portion of the project is to obtain information on manpower requirements and costs of packaged plants for the treatment of sanitary wastewater; for the purposes of this study we are using the following definition for a package plant: "a complete wastewater treatment plant designed, fabricated and assembled at a manufacturing location and transported to the treatment site where it is installed and connected to the influent and effluent pipes." We are interested in those plants with steel or pre-case concrete basins rather than poured concrete basins.

An objective of this project is to provide information which would be useful in formulating and evaluating manpower development and training programs directed to increasing the supply of qualified personnel in this sector of the water pollution control effort. Another objective is to develop information on costs of purchasing and installing package plants and of operating them. It is intended that the report from this project would be made available nationally to consulting engineers and government agencies at the Federal, state and local levels for the planning and staffing of new plants and evaluating the staff and costs of existing plants in order to improve their operations, maintenance, and organization.

We solicit your assistance on a voluntary basis. The type of information we are interested in includes: (1) list prices F.O.B. your plant for all package plants under 2,000 GPD and then for the following sizes in GPD: 2,000; 3,000; 4,000; 5,000; 7,500; 10,000; 15,000; 20,000; 30,000; 40,000; 50,000; 60,000; 80,000; 100,000; 120,000; and 150,000 (if you do not manufacture plants in any of these sizes, those closest would be suitable); (2) other cost data, such as operation and maintenance costs; (3) estimated life or actual life if some of your plants have been removed from service; (4) operation and maintenance manuals and related brochures; (5) reliability information; and (6) operational study data (including National Sanitation Foundation reports, if available).

If you feel that plants larger than 150,000 GPD are package plants according to the above definition, please include cost information for them also.

In order to be able to fully utilize the cost information, we would appreciate knowing what is included in the cost figures (i.e., is a service fee included in the purchase price; is installation included in the purchase price; what is the cost of optional equipment, etc.).

Cost information that you send us will be kept confidential; we will report only average cost figures and not costs of specific plants by company.

We would like to visit a few of your package plants in operation. Could you please send us the location of a representative sample by size, type of operation, type of process and type of user (motel, city, etc.). Approximately six plants in each state you serve would be ample (Iowa, Illinois, Indiana, Ohio, southern Minnesota, Michigan and Wisconsin, northern Missouri and eastern Kansas, Nebraska and South Dakota.).

Thank you for your cooperation.

Sincerely,

George E. Lamp, Jr.
Assistant Professor

GEL/jkl

LETTER TO OWNERS OF PACKAGE PLANTS

IOWA STATE
UNIVERSITY

Department of Industrial Engineering
212 Marston Hall
Ames, Iowa 50010

Telephone 515-294-1682

The Environmental Protection Agency, Office of Water Programs, Manpower Development Staff, has awarded a grant to the Industrial Engineering Department of Iowa State University for a project entitled, "Estimating Manpower Requirements and Selected Cost Factors for Small Wastewater Treatment Plants."

One portion of the project is to obtain information on manpower requirements and costs of packaged plants for the treatment of sanitary wastewater; for the purposes of this study we are using the following definition for a package plant: "a complete wastewater treatment plant, designed, fabricated and assembled at a manufacturing location and transported to the treatment site where it is installed and connected to the influent and effluent pipes." We are interested in those plants with steel basins rather than poured concrete basins.

An objective of this project is to provide information which would be useful in formulating and evaluating manpower development and training programs directed to increasing the supply of qualified personnel in this sector of the water pollution control effort. Another objective is to develop information on costs of purchasing and installing package plants and of operating them.

We understand that you utilize a package plant and solicit your assistance on a voluntary basis. Could we visit you some time, preferably during the week of July 31 to August 4? We would like to obtain specific cost information from whoever keeps the records; and we would like to visit with the operator of the package plant as to the work he does, etc., and to observe him as he performs his duties.

Let me assure you that we are not evaluating either you or your plant. The information you give us will be kept strictly confidential.

If we may visit you, please indicate what dates would be most suitable. Also, could you please send us the following information about your plant: manufacturer, capacity, type of process (extended aeration, contact stabilization, etc.) and method aeration (diffused air, mechanical or turbine, etc.). May we please have your reply by July 24?

Thank you for your cooperation.

Sincerely,

George E. Lamp, Jr.
Assistant Professor

GEL/jkl

APPENDIX II-D. List of package plant manufacturers who responded to letter survey

1. Manufacturers of package plants

Aera-Filt Systems, Inc.
P.O. Box 567
Lafayette, Ind. 47901

Ber-Nel Sewage Treatment Plant
Division of Nelson Septic Tank Co.
Route #1, Box 169
Union Grove, Wisc. 53182

BIO_2 Systems, Inc.
3306 Wyoming
Kansas City, Mo. 64111

Can-Tex Industries
P.O. Box 340
Mineral Wells, Texas 76067

Walker Process Equipment, Inc.
Division of Chicago Bridge & Iron Co.
Aurora, Ill. 60506

Chicago Pump, Hydrodynamics Division
FMC Corporation
622 West Diversey Parkway
Chicago, Ill. 60614

Clow Corporation
P.O. Box 324
Florence, Ky. 41042

Coolbroth-Sitton Septic Tanks, Inc.
4810 West Medicine Lake Drive
Minneapolis, Minn. 55442

Davco Manufacturing Company
1828 Metcalf Avenue
Thomasville, Ga. 31792

Demco, Inc.
P.O. Box 94700
Oklahoma City, Okla. 73109

Dickey, W. S. Clay Manufacturing Co.
P.O. Box 6
Pittsburg, Kan. 66762

The Eimco Corp.
537 West Sixth South
P.O. Box 300
Salt Lake City, Utah 84110

Environmental Health Research
Cromaglass Division
The Cromar Co.
Box 1146
Williamsport, Pa. 17701

Environmental Service(s), Inc.
1319 Rose Avenue
Yak, Pa. 17403

Environment/One Corporation
2773 C Balltown Road
Schenectady, N.Y. 12309

Extended Aeration
P.O. Box 822
Huntington, W. Va. 25712

Fifer Corporation
P.O. Box 13175
Louisville, Ky. 40213

Flgyt Corporation
129 Glover Avenue
P.O. Box 857
Norwalk, Conn. 06856

Gulf Environmental Systems
Gulf Degremont
P.O. Box 608 Roga Division
San Diego, Calif. 92112

Jet Aeration Company
9911 Elk Avenue
Cleveland, Ohio 44108

Marolf, Inc.
1620 N. Hercules Avenue
Clearwater, Fla. 33515

Microphor, Inc.
475 East San Francisco Avenue
Willits, Calif. 95490

Multi-Flo, Inc.
500 Webster Street
Dayton, Ohio 45401

Nayadic Sciences, Inc.
Village of Eagle
1205 W. Chester
West Chester, Pa. 19380

New England Wastewater Systems, Inc.
Route 100
P.O. Box 412
West Dover, Ver. 05356

Nishihara Environmental Sanit. Res. Co.
% Dr. Takashi Asano
Montana State University
Department of Civil Engineering
Bozeman, Mont. 59715

Norwalk Vault Co.
Norwalk, Ohio 44857

Peabody-Hart
Hart Pump Corporation
150 Willard Avenue
Newington, Conn. 06111

Plast-A-Form Corporation
225 Valley Street
Williamsport, Pa. 17701

Pollution Control Devices, Inc.
P.O. Box 31104
Aurora, Colo. 80010

Pollution Control Systems, Inc.
10575 West 120th Avenue
P.O. Box 401
Broomfield, Colo. 80020

Pollutrol Technology Inc.
P.O. Box 3727
Portland Me. 04104

Purestream Industries, Inc.
618 Buttermilk Road
Covington, Ky. 41011

Smith and Loveless – Division
Union Tank Car Company
96th and Old Santa Fe Trail
Lenexa, Kan. 66215

Suburbia Systems, Inc.
P.O. Box 6217
Leawood, Kan. 66206

Thor-Bec Corp.
Air-Gest International Corp.
6484 Victoria Avenue
Suite 201
Montreal, Canada

Westinghouse Electric Corporation
Infilco Division
401 East Main Street
Richmond, Va. 23216

Wisconsin Plumbing and Heating
Supply Co.
822 South 2nd Street
Milwaukee, Wisc. 53204

2. Manufacturers of package plants who did not send cost data

Autotrol Corporation
5855 North Glen Park Road
Milwaukee, Wisc. 53209

Defiance Company
Division of Davco Industries
P.O. Drawer 186
Tallevast, Fla. 33588

International Waste Controls, Inc.
580 Sylvan Avenue
Englewood Cliffs, N.J. 07632

Keene Corporation
Water Pollution Control Division
1740 Molitor Road
Aurora, Ill. 60507

Lyco Systems, Inc.
P.O. Box 569
Williamsport, Pa. 17701

Mack Industries
P.O. Box 335
Valley City, Ohio 44280

Permutit Company
Division Sybron Corporation
49 East Midland Avenue
Paramus, N.J. 07652

Polcon Corporation
222 Cedar Lane
Teaneck, N.J. 07666

Pollution Control, Inc.
Suite 21
Lunken Airport Administration Bldg.
Cincinnati, Ohio 45226

Topco Company
Division of Sterling-Salem Corporation
P.O. Box 507
Salem, Ohio 44460

Water Pollution Control
Corporation – Sanitaire
P.O. Box 744
2401 North Maryland Avenue
Milwaukee, Wisc. 53201

World Ecolog Systems Co.
Division of Purification Sciences Inc.
One Pure Water Terrace
Seneca Falls, N.Y. 13148

3. Manufacturers who do not manufacture package plants at the present time but plan to in the future

Aero-Hydraulics Corp.
10340 Cote de Liesse
Lachine, Quebec
Canada

Chemetics Ltd.
1827 W. 5th Avenue
Vancouver, Canada

Hawker Siddeley Canada Ltd.
1660 Station Street
Vancouver, Canada

Neptune Micro-Floc Inc.
P.O. Box 612
Corvallis, Ore. 97330

4. Manufacturers of ship board units

Fairbanks Morse, Inc.
Colt Industries
701 Lawton Avenue
Beloit, Wisc. 52511

John Misener Marine Equipment Ltd.
1 Marina Drive
Port Colborne, Ontario
Canada

Pall Corporation
30 Seacliff Avenue
Glen Cove, L.I., N.Y. 11542

5. Manufacturers of plants which did not fall within the specific definition of package plants used for this study

Anticimaxbolagen (Wallax)
Fach, S-101 10
Stockholm 1, SWEDEN

AWT Systems, Inc.
910 Market Street
Wilmington, Dela. 19899

Canatraco Ltd.
Suite 385
Montreal 249, Canada

Chem Pure, Inc.
3460 Hollenburg Drive
Bridgeton, St. Louis County, Mo. 63044

Dorr-Oliver, Inc.
Havemeyer Lane
Steamford, Conn. 06904

APPENDIX II-E. List of package plant manufacturers who did not respond to letter contact or were not contacted, but who were mentioned in the literature as manufacturers of package plants in a general sense

Arrow Company, Inc.
1260 Bayson Road
Columbus, Ohio 43229

R. P. Adams Company, Inc.
237 E. Park Drive
Buffalo, N.Y. 14240

Aerojet General Corporation
9200 East Flair Drive
El Monte, Calif. 91734

Airesearch Manufacturing Company of Arizona
402 South 36th Street
Phoenix, Ariz. 85934

Allenaire, Inc.
379 Niles-Cortland Road SE
Warren, Ohio 44484

American Bowser Corporation
100 North Broadway
Aurora, Ill. 60505

American Environmental Systems Company
35-10T Broadway
Long Island City, N.Y. 11105

American Schreiber Company
R.D. 2
Red Lion, Pa. 17356

Ames Crosta Mills (Canada) Ltd.
105 Brisbane Road
Downsview, Ontario, Canada

Anthes Eastern Ltd.
Penberthy Division
P.O. Box 1009
St. Catharines, Ontario, Canada

Aqua-Aerobic Systems, Inc.
6306 North Alpine Road
Rockford, Ill. 61111

Aquaneering Division of Scott & Fetzer Co.
13110 Enterprise Avenue
Cleveland, Ohio 44101

Aquanox, Inc.
140 Sylvan
Englewood Cliffs, N.J. 07632

Aquatair Corporation
111 West 1st Street
Dayton, Ohio 45401

Armon Systems, Inc.
Tyler, Texas 75701

Atlantic Bridge Co., Ltd.
Luenburg, Nova Scotia
Canada

BCA Industrial Controls, Ltd.
344 Lynn Avenue
N. Vancouver, Canada

Beloit-Passavant Corporation
Janesville, Wisc. 53545

Besser Wasteco Corporation
Roanoke, Ill. 61561

BIF, Unit of General Signal Corp.
345 Harris Avenue
Providence, R.I. 02901

Bluffton Septic Tank Company
Bluffton, Ohio 45817

Brink Equipment Engineering Sales
Inorganic Chemical Division
800 North Lindbergh Blvd.
St. Louis, Mo. 63166

Cherne Industries
5701 S. Country Road 18
Edina, Minn. 55436

Convert-All, Inc.
Brunswick, Me. 04011

Converto Company of Canada Ltd.
1115 Sherbrooke Street, West
Suite 2603
Montreal, Canada

Deady Chemical
3155 Fiberglas Road
Kansas City, Kan. 66115

Dearborn Chemicals
W. R. Grace & Co.
Chicago, Ill. 60690

Defiance of Arizona
4829 N. 19th Avenue
Phoenix, Ariz. 85015

Dependable Sewage Equipment Co.
3404 Deshler Avenue
Columbus, Ohio 43216

Devine, J. A. & Associates, Ltd.
33 Guardsman Road
Thornhill, Ontario, Canada

Dravo Corp.
Water and Waste Treatment Dept.
1 Oliver Plaza
Pittsburgh, Pa. 15222

E. I. DuPont DeNemours & Co., Inc.
1007 Market Street
Wilmington, Dela. 19898

Ecological Science Corporation
20215 N.W. 2nd Avenue
Miami, Fla. 33169

Eldib Engineering & Research, Inc.
170 Blanchard Street
Newark, N.J. 07105

Envirotech Corporation
770 Welch Road
Palo Alto, Calif. 74304

Fielding, Hugh R., Ltd.
55 Glen Cameron Road
Thornhill, Ontario, Canada

Fostoria Vault Company
R.R. #3
Fostoria, Ohio 44830

Frame Company
Providence, R.I. 02904

General Electric Company
ReEntry & Environ. Systems Div.
Urban Systems Program Department
3198 Chestnut Street
Philadelphia, Pa. 19101

Hankin, Francis & Co., Ltd.
7445 Chester Avenue
Montreal 265, Canada

Hersey-Sparing Meter Co.
4097 N. Temple City Blvd.
El Monte, Calif. 91731

Hills-McCanna Company
400 Maple Avenue
Carpentersville, Ill. 60110

Hinde Engineering Co.
654 Deerfield Road
Highland Park, Ill. 60035

Hydromation Engineering Company
39203 Amrhein
Livonia, Mich. 48150

Johns-Manville Corp.
22 E. 40th Street
New York, N.Y. 10016

Lakeside Engineering Corp.
222 West Adams Street
Chicago, Ill. 60606

Litton Systems, Inc.
Applied Sciences Division
2033 E. Hennepin Avenue
Minneapolis, Minn. 55143

Magnor, Inc.
190 Industrial Blvd.
Boucherville, Quebec, Canada

Masdom Corporation, Ltd.
83 Sunrise Avenue
Toronto 16, Canada

Met-Pro
505 Mitchell
Lanedale, Pa. 19445

Napanee Industries
51 Ann Street
Napanee, Ontario, Canada

Neptune Meter Company
630 Fifty Avenue
New York, N.Y. 10017

O'Brien Manufacturing Corp.
5630 T Northwest Highway
Chicago, Ill. 60646

Ozone Research & Equipment Corp.
3840 North 40th Avenue
Phoenix, Ariz. 85019

Peacock Brothers, Ltd.
P.O. Box 1040
Montreal 101, Canada

The Peerless Company
A. E. Stevenson
24607 Emery Road
Cleveland, Ohio 44128

Perfex Corporation
500 W. Oklahoma Avenue
Milwaukee, Wisc. 53207

Pollution Control Division/FWI
Department 10
Hagerstown, Md. 21740

Puretronics
Warren, Mich. 48089

Red Jacket Manufacturing Company
P.O. Box 3888
Davenport, Iowa 52808

Resources Control, Inc.
Frontage Road
West Haven, Conn. 06516

Richards of Rockford, Inc.
P.O. Box 2121
Rockford, Ill. 61111

Sanitherm Engineering, Ltd.
1727 West 2nd Avenue
Vancouver 9, Canada

Security Sewage Equipment Co.
4864 Henry Street
Cleveland, Ohio 44125

Sewerless Toilet Company
Lafayette, Ind. 47901

Sirco Products, Ltd.
8815 Selkirk Street
Vancouver 14, Canada

Svenska Interpur AB
Stockholm
Sweden

Tailor and Company, Inc.
2403 State Street
Bettendorf, Iowa 52722

Thiokol Chemical Corporation
Wasatch Division
Salt Lake City, Utah 84101

Ultradynamics Corporation'
6 Wait Street
Paterson, N.J. 07524

Valdespino Labs
Orlando, Fla. 32802

Vogt Brothers Mfg. Co.
18th and Main Streets
Louisville, Ky. 40203

Water and Sewage, Inc.
P.O. Box 5577
Daytona Beach, Fla. 32020

Welles Products Corporation
1600 N 2nd Street
Roscoe, Ill. 61073

Westaway, W. J., Ltd.
P.O. Box 100
Station B
Hamilton, Ontario, Canada

Western Water Equip. Co.
925 Tanklage Road
San Carlos, Calif. 94070

Wilson Water Purification Corp.
2371 Broadway
Buffalo, N.Y. 14240

Zurn Industries, Inc.
Erie, Pa. 16512

APPENDIX II-F. Forms for collecting manpower data from operating package plants

Task - Frequency - Time Form

1. Tasks Associated with Screening & Comminuting:

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Hand cleaning of screens				
(b) Removal and disposal of debris (screenings)				
(c) Comminuter cleaning				
Others -- List				
(d)				
(e)				

2. Tasks associated with aeration basin: (Type of aeration ______________________)

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Scum removal				
(b) Cleaning baffles, weirs, and scum removal equipment				
Others -- List				
(c)				
(d)				

3. Tasks associated with Imhoff Tanks:

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Clean slots				
(b) Squeegee sides				
(c) Scum removal				
(d) Sludge removal				
(e) Inspection & flow adjustment				
(f) Measuring sludge depth				
(g) Agitate gas vents				
(h) Cleaning walls and weirs				
Others -- List				
(i)				
(j)				

4. Tasks associated with Final Settling Tank:

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Adjustment of return sludge pumping				
(c) Scum removal				
(d) Cleaning walls, weirs, center walls and scum removal equipment				
Others -- List				
(e)				
(f)				

5. Tasks associated with aerobic digester:

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Scum control				
(b) Withdrawal of supernatent				
(c) Cleaning of scum control equipment				
Others -- List				
(d)				
(e)				

6. Tasks associated with disposal of wasted sludge:

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Withdrawal of wasted sludge				
(b) Finishing pond				
(c) Burial				
(d) Landfill				
(e) Spreading of wasted sludge				
Others -- List				
(f)				
(g)				

7. Tasks associated with laboratory control:

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
Influent and Effluent Solids determination				
(a) Total solids				
(b) Suspended solids				
(c) Settleable solids				
(d) Volatile solids				
(e) COD				
(f) Wastewater temperature and color				
(g) BOD influent				
(h) BOD effluent				
(i) pH				
(j) Dissolved oxygen				
(k) Relative stability				
Digested Sludge Solids				
(l) % total solids				
(m) % volatile solids				
(n) 30 minute settling test				
(o) Mixed liquor suspended solids				
(p) Sludge volume or sludge density index				
(q) Dishwashing				
(r) Recordkeeping				
(s) Lab maintenance				
(t) Weather				
Others -- List				
(u)				
(v)				

8. Ta... ...ated w... housekeeping and yardwork.

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Mowing grass				
(b) Painting (fences, tanks, etc)				
Others -- List				
(c)				
(d)				

9. Tasks associated with inspection and maintenance:

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Inspection of mechanical devices				
(b) Maintenance of air diffuser devices				
(c) Maintenance of air blowers				
(d) Maintenance of mechanical aerators				
(e) Maintenance of other mechanical equipment				
(f) Inspection of electrical devices				
(g) Maintenance of electrical motors and other devices				
Others -- List				
(h)				
(i)				

10. Miscellaneous Tasks:

Task Activity	Performed By	Frequency of Performance (Times per d;w;m)	Average Duration (in Min) of each Performance	# of Personnel Required each time Performed
(a) Planning				
(b) Supervision				
(c) Training				
(d) Housekeeping on package plant				
(e) Flow measurement				
(f) Recordkeeping (not recorded earlier)				
Others -- List				
(g)				
(h)				
(i)				

Individual Job Analysis Questionnaire

Your cooperation in gathering data on the different tasks associated with package plant wastewater treatment is very much appreciated.

1. What is your job title? ______________________________

2. Location of plant ______________________________

3. Describe in your own words your work with the package plant, what you do, your responsibilities, and whom you work with.

4. What is the source of the information required for effective job performance (such as handbooks, operating manuals, blueprints, consultants, government personnel, journals, manufacturer's representative or distributor, etc.)?

5. What contacts are you required to make with persons other than your immediate supervisor (such as government people, maintenance people, sales representatives, etc.)?

6. What problems do you normally discuss with your supervisor before making a decision?

7. What kinds of problems and decisions do you refer to your supervisor?

8. Describe the nature of your responsibility for money, facilities and reports (for example, how much can you spend for supplies, maintenance service, etc. without obtaining authorization from your supervisor)?

9. What information do you relay to other persons (such as to your supervisor or the state board of health, etc)?

10. For those tasks which you do not perform on a routine, scheduled basis, what indicates that they need to be done.

11. Which tasks must be essentially error free for satisfactory job performance?

12. What guideline do you use as a basis for evaluating your work performance?

13. What job or jobs of a higher classification does this job prepare one for?

14. What job or jobs prepare a worker for this job assignment?

15. What level of education is required to perform your job?

16. Describe any vocational preparation which is necessary for performing your job. Indicate the length of time needed to obtain this preparation.

17. (a) What percentage of the time do you spend in the following working positions?
Standing _______% Sitting _______% Walking about _______%
(b) What weight in pounds must you personally lift and carry? _______ lbs.
(c) What percentage of the working day do you actually spend lifting and carrying this weight? _______%
(d) Are their any special physical skills, eye-hand coordination, and manual dexterity skills required on your job? If yes, please explain.

18. Describe any working conditions associated with your job, such as noise, extremes of cold or heat, dust, fumes, toxic conditions, etc., which you consider unfavorable or disagreeable.

19. Describe the dangers or accident hazards present in your job.

20. An aspect of your job may require that you work with DATA, often in the form of numbers, words and symbols; or ideas and verbal instructions. Which of the following statements are representative of your job? Check all the appropriate ones.

_____ I compare readily observable data and information with given and fixed standards and act according to instructions.

_____ I copy, transcribe or post data to appropriate records

_____ I perform arithmetic operations and report on and/or carry out a prescribed action in relation to them.

_____ I compile, gather, collate, or classify information about data, people, or things. Reporting and/or carrying out a <u>prescribed</u> action in relation to the information is <u>frequently</u> involved.

_____ I analyze, examine and evaluate data. The presentation of alternative actions in relation to the evaluation is frequently involved.

_____ I coordinate activities, and determine time, place, and sequence of operations or actions to be taken on the basis of analysis of data.

21. Your job also may require that you work with PEOPLE. Which of the following statements are representative of your job? Check all the appropriate ones.

_____ I follow instructions, attending to the needs or requests of others.

_____ I talk with and/or signal people to convey or exchange information.

_____ I supervise others, determining work procedures, assigning specific duties to them, maintaining harmonious relations among them, and promoting efficiency.

_____ I instruct, teach or train others, through explanation, demonstration, and supervised practice.

_____ I exchange ideas, information, and opinions with others to formulate policies and programs and/or arrive jointly at decisions, conclusions, or solutions.

22. Your job may also require that you work with THINGS, inanimate objects like machines, tools, equipment and products. Something which has shape, form, and other physical characteristics. Which of the following statements are representative of your job? Check all the appropriate ones.

_____ I use body members (hands, arms, legs, etc.), handtools, and/or special devices to work, move, or carry objects or materials. This involves little or no latitude for judgment with regard to attainment of standards or in selecting the appropriate tool, object, or material.

_____ I insert, throw, dump, or place materials in or remove them from machines or equipment which are automatic or are tended or operated by other workers.

_____ I tend, start, stop, and observe the functioning of machines and equipment. This involves adjusting materials or controls of the machine, such as changing guides, adjusting timers and temperature gages, turning valves to allow flow of materials, and flipping switches in response to lights. Little judgment is involved in making these adjustments.

_____ I use body members (hands, arms, legs, etc), tools, or special devices to work, move, guide, or place objects or materials. This involves some latitude for judgment with regard to precision attained and selecting appropriate tool, object, or material, although this is readily evident.

_____ I start, stop, and control the actions of machines or equipment for which a course must be steered, or which must be guided, in order to fabricate, process, and/or move things or people. Involves such activities as observing gages and dials; estimating distances and determining speed and direction of other objects; turning cranks and wheels; pushing clutches or brakes; and pushing or pulling gear lifts or levers. Includes such machines as cranes, tractors, and hoisting machines.

_____ I operate and control by starting, stopping, and adjusting the progress of machines or equipment designed to fabricate and/or process objects or materials. Controlling equipment involves observing gages, dials, etc., and turning valves and other devices to control such factors as temperature, pressure, flow of liquids, speed of pumps, and reactions of materials.

_____ I use body members (hands, arms, legs, etc) and/or tools or work aids to work, move, guide, or place objects or materials in situations where ultimate responsibility for the attainment of standards occurs and selection of appropriate tools, objects or materials, and the adjustment of the tool to the task requires exercise of <u>considerable</u> judgment.

_____ I set up and adjust machines or equipment by replacing or altering tools, jigs, fixtures, and attachments to prepare them to perform their functions, change their performance, or restore their proper functioning if they break down.

APPENDIX II-G. Form for collecting cost data from operating package plants

PACKAGE PLANT COST DATA

I. GENERAL INFORMATION

1. Plant location ____________________
2. Person interviewed ____________________ Date __________
3. Design capacity ____________________ gpd.
4. Population served ____________________
5. Average daily flow ____________________ gpd.
6. Plant manufacturer ____________________
7. Type of process ____________________
8. Model number ____________________
9. Date installed ____________________
10. Description of plant layout ____________________

    ____
11. Area for package plant ____________________
12. Area for lagoon ____________________
13. Expenditures incurred more than one year prior to first use of plant ___

    ____

II. DATA ON INITIAL COSTS (First Costs)

1. Costs associated with site acquisition
   a. Purchase price __________
   b. Other __________ __________
   c. Other __________ __________ __________
2. Costs associated with the package plant
   a. Base purchase price __________
   b. Sales tax __________
   c. Freight __________
   d. Site preparation __________
   e. Installing and connecting to power & influent & effluent lines __________
   f. Electrical work (other than connecting power line to panel) __________

g. Start up costs ____________

h. Other ____________ ____________

i. Other ____________ ____________ ____________

3. Costs associated with the lagoon

a. Site preparation & construction ____________

b. Piping ____________

c. Other ____________ ____________ ____________

4. Costs associated with landscaping & yardwork

a. Fencing ____________

b. Driveway and parking ____________

c. Sidewalks ____________

d. Landscaping ____________

e. Other ____________ ____________ ____________

5. Costs associated with administrative building, laboratory, garage, and maintenance equipment.

	Item	Cost	
a.	____________	____________	
b.	____________	____________	
c.	____________	____________	____________

6. Engineering & design costs

a. Engineering Consultant ____________

b. Other ____________ ____________

c. Other ____________ ____________ ____________

7. Administrative costs associated with design, installation and startup.

a. Supervision ____________

b. Contract writing ____________

c. Legal fees ____________

d. Other ____________

e. Other ____________ ____________

	Item	Cost
a.	____________	____________
b.	____________	____________
c.	____________	____________

Total ____________

III. Costs associated with replacement of major items (and when)

	Item	Time	Cost
1.	____________	________	________
2.	____________	________	________
3.	____________	________	________

IV. OPERATING EXPENSES

1. All labor costs

	Ave. manhours Individual Job*/week			/year	Wage rate	Fringe Benefits	Total
a.	______	___	___	___	___	______	______
b.	______	___	___	___	___	______	______
c.	______	___	___	___	___	______	______
d.	______	___	___	___	___	______	______
e.	______	___	___	___	___	______	______

f. Other ____________________ ______

g. Other ____________________ ______ ______

2. Costs associated with testing

   a. Internal (purchase of testing equipment and supplies, etc.) ________

   b. External (payments to testing labs, mailing, transp. costs) ________

   c. Other ____________________ ________

3. Power Costs (cost/kwh ____________)

	Motor Location	h.p. rating	Ave. hrs/day	running time hrs/yr.	kwh/ year	cost/ year
a.	______	______	______	______	___	___
b.	______	______	______	______	___	___
c.	______	______	______	______	___	___
d.	______	______	______	______	___	___

e. Other ____________________ ________

VII. ADMINISTRATIVE COSTS

1. Office supplies & expensed equipment ____________

2. Repair & maintenance of office, laboratory and garage facilities ____________

3. Travel expenses ____________

4. Training expenses including operator certification ____________

5. Accounting expenses ____________

6. Telephone & postage, insurance, legal services, auditing, taxes ____________

7. Miscellaneous

	Item	Cost	
a.	____________	____________	
b.	____________	____________	____________
		Total	____________