CHAPTER VI

ECONOMIC CONSIDERATIONS

Due to the mentioned experimental studies. It appears to be some important aspects that need further verifications and detailed studies.

A general comparision of the existing systems to the new development, the reclamation system for reuse, on the basis of annual costs and unit production costs will be mentioned as follows. Since this experiment is mainly based upon the reclamation system,therefore,the changes of any variables such as out-put capacity, service life of equipments, the percentage of operation and maintenance costs and the interest rate of the system will significantly affect the final production cost of the used water. The effects due to the mentioned variables obtained from the analysis will be given in details further on.

Design of the Reclamation System

Due to the lay - out of the reclamation system, shown in Fig.30. The water for washing will flow from the storage tank. After using, it will recyclicly flows back to the filter tank by flows through the concrete trough, grease trap basin, the raw water tank and it will be pumped through the filter tank respectively. The flow along the automobile - wash area will be blocked by the concrete curb to prevent washed water flow out of this area and blocked by means of the elevated inner side of concrete trough which lays between the grease trap basin and the raw water tank in order to control the flow recycles back must flow through grease trap basin before to raw water tank.

As the results from the previous chapter. The average water consumption, referred to being used as car washing, of the

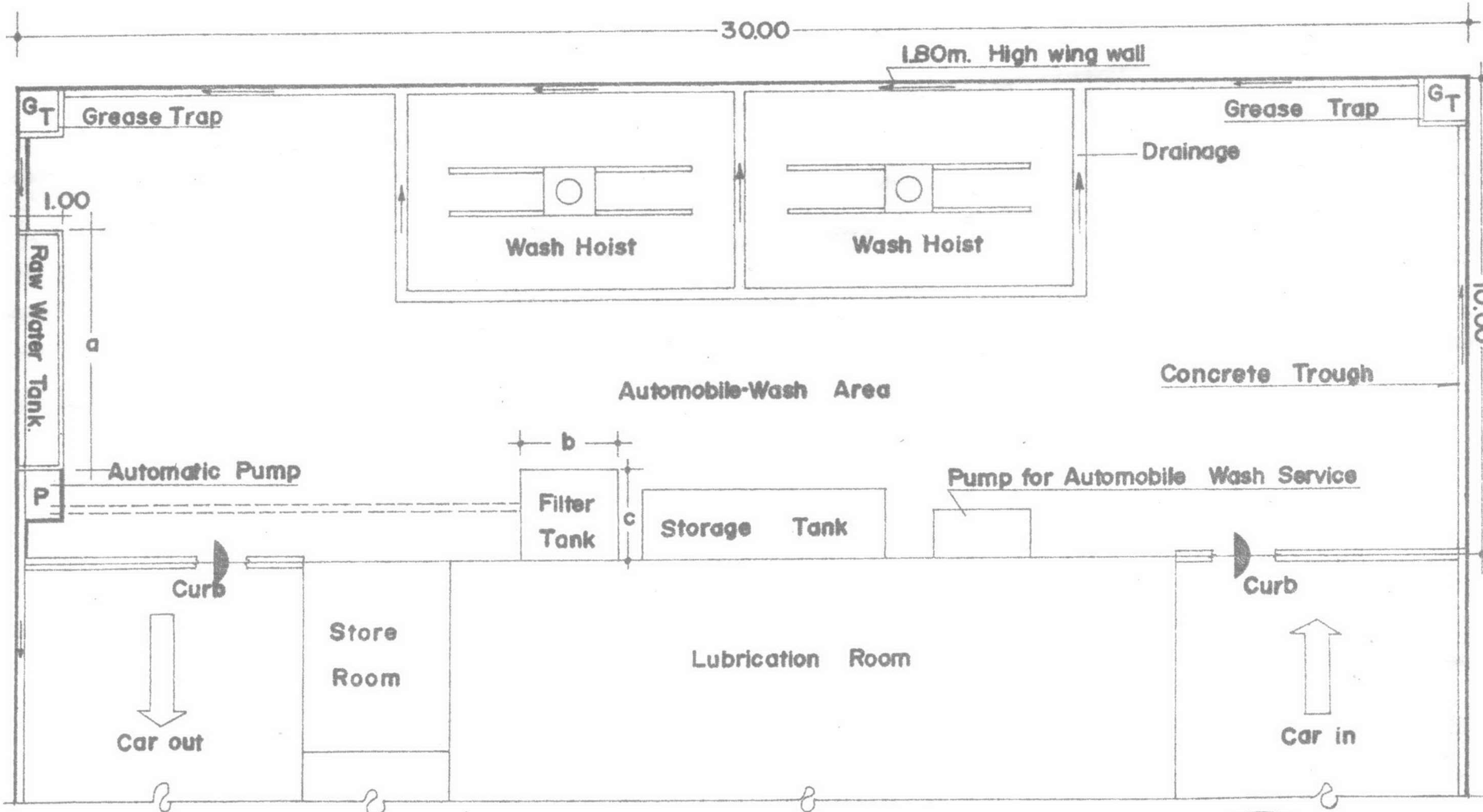


Fig. 30 LAY-OUT OF RECLAMATION SYSTEM.

service stationsis provided into 4 categories according to the service periods. These categories will be mentioned in terms of the washing capacities which are 40, 60 and 80 m^3/day these three capacities will be served for a service period of 24 hours and the last one is 20 m^3/day capacity, with the service period of 12 hours.

The useful figures for designing the filter obtained from the experiment on the model filter resulted from the previous chapter show that :

- the optimum filtration rate of 1.25 m^3/m^2/hr,
- the optimum depth of the filter media, the burnt rice husk, of 0.80 m, and
- the filter resistance, head loss, was built up to 1.2 m after the filter run period of about 152 hours.

These above data can, therefore, finally be used as the criteria in designing the reclamation system. This case, with the ratio of the peak water demand and the average water demand of about 1.10 to 1.20, the filter capacity of the system should be about 1.5 times the average water demand. And with the help of "the influent rate control system (CLEASBY, 1969)" the filter can easily be designed.

Such the above method the constant rate of the influent can be more simply control rather than the controlling of the effluent rate. Consequently the rate of the effluent will be constant and always equal to the rate of the influent because during the head loss of the filter is getting higher the water level in the filter tank will gradually rise until the sufficient water level balances the higher filter head loss to gain the constant rate of the effluent and always equal to the constant inflow rate. The results of raising water level slowly and smoothly will provide the least harmful effect to the filtered water quality.

Besides, the filter head loss can be evidently observed by the operators by means of a simple manometer attached to the filter tank wall. When the water level reaches the maximum level, cleaning of the filter bed, by means of skimming, will be required.

The depth of the filter tank has been determined by summing up of the depth of the underdrainage system; the depth of the filter media, the burnt rice husk; the depth of supernatant water and the available head loss respectively. Generally the value of the available head loss is approximately 1.2 m and the depth of the supernatant water above the filter bed is about 20 cm in order to avoid air- binding in the filter bed and prevent the disturbance in the filter bed, the burnt rice husk,from the incoming water. The depth of the burnt rice husk referred as the filter media is about 0.80 m and the depth of the underdrainage system of about 0.20 m. The underdrainage system of the filter has been designed in such a way that the filtrate would be accumulated evenly over the entire filtering area and no penetration of the burnt rice husk into would be occured. The criteria (FAIR & GEYER, 1968 PP. 27 - 29) for designing the underdrainage system based on :

Ratio of the area of the orifice to the area of bed served $(1.5 \text{ to } 5) \times 10^{-3} : 1$

Diameter of the orifices	$\frac{1}{4}$" to $\frac{3}{4}$"
Spacing of orifices	3 to 12 inches on centers.

According to the structural design of the filter tank and the raw water tank. The concrete mixture, cement: fine aggregate: coarse aggregate, should be 1 : 1.5 : 3 the method of calculation should be done according to VAZIRANI method (VAZARANI and RATWANI, 1972). Details of filter tank and Raw water tank of the 4 mentioned capacities has been illustrated in Table 15 and Figs. 31 to 34.

Table 15 Filter Descriptions of Various Groups of Service Stations

	Item	Unit	Group of Service Station			
			No.1	No.2	No.3	No.4
1	Av. Water Demand	m^3/day	20	40	60	80
2	Max. Demand = 1.5 X Av.	m^3/day	30	60	90	120
3	Filter Capacity	m^3/day	33.75	67.50	90.00	120.00
4	Filtration Rate	$m^3/m^2/hr$	1.25	1.25	1.25	1.25
5	Operating Hours for av.demand	hr/day	7.11	14.22	16	16
6	Duration of Run for av.demand	day	20	10	9	9
7	Size of Filter Tank :					
	Width (c)	m	1.50	1.50	1.50	2.00
	Length (b)	m	1.50	1.50	2.00	2.00
	Depth	m	2.75	2.75	2.75	2.75
8	Depth of Media					
	Burnt Rice Husk	m	0.80	0.80	0.80	0.80
	Supporting Gravel					
	Top : $\frac{1}{8}$" to $\frac{1}{4}$" ø	m	0.05	0.05	0.05	0.05
	Middle : $\frac{3}{8}$" to $\frac{1}{2}$" ø	m	0.05	0.05	0.05	0.05
	Bottom : $\frac{3}{4}$" to 1" ø	m	0.10	0.10	0.10	0.10
9	Size of Raw Water Tank :					
	Width	m	1.00	1.00	1.00	1.00
	Length (a)	m	3.00	3.00	4.00	5.00
	Depth	m	1.65	1.65	1.65	1.65

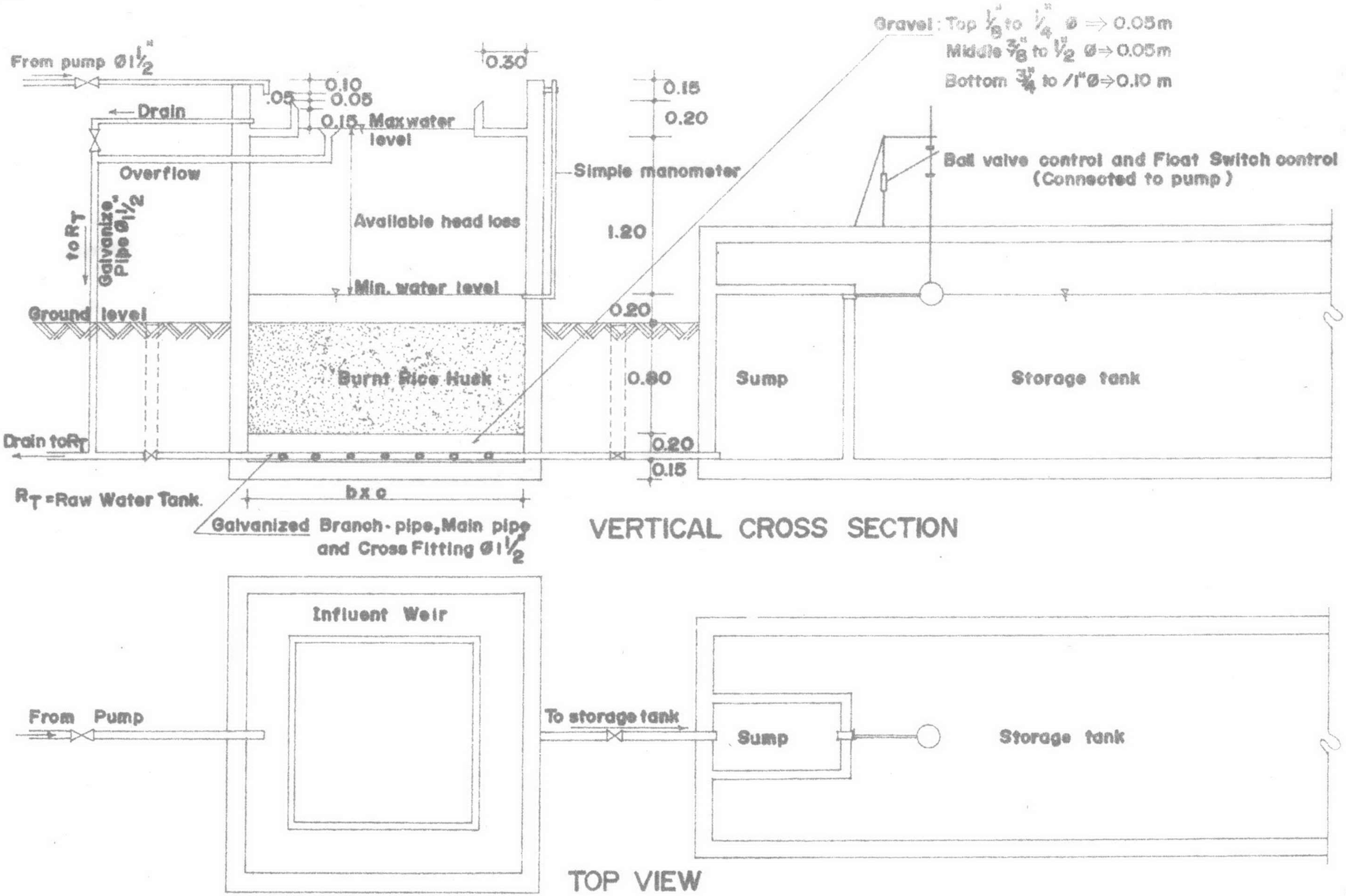


Fig. 31 DETAIL OF FILTER ARRANGEMENT

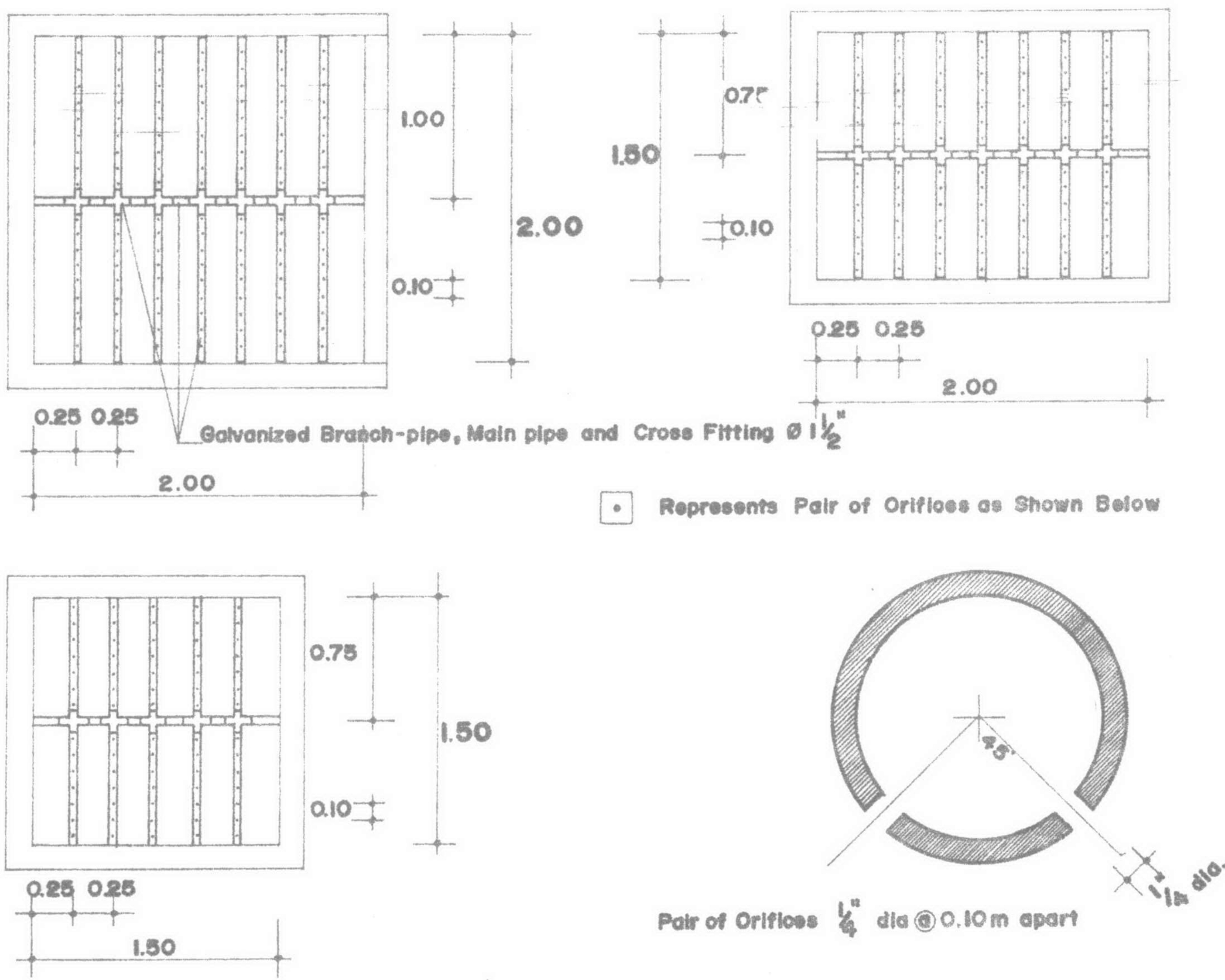


Fig. 32 DETAILS OF UNDERDRAINAGE OF FILTER TANKS.

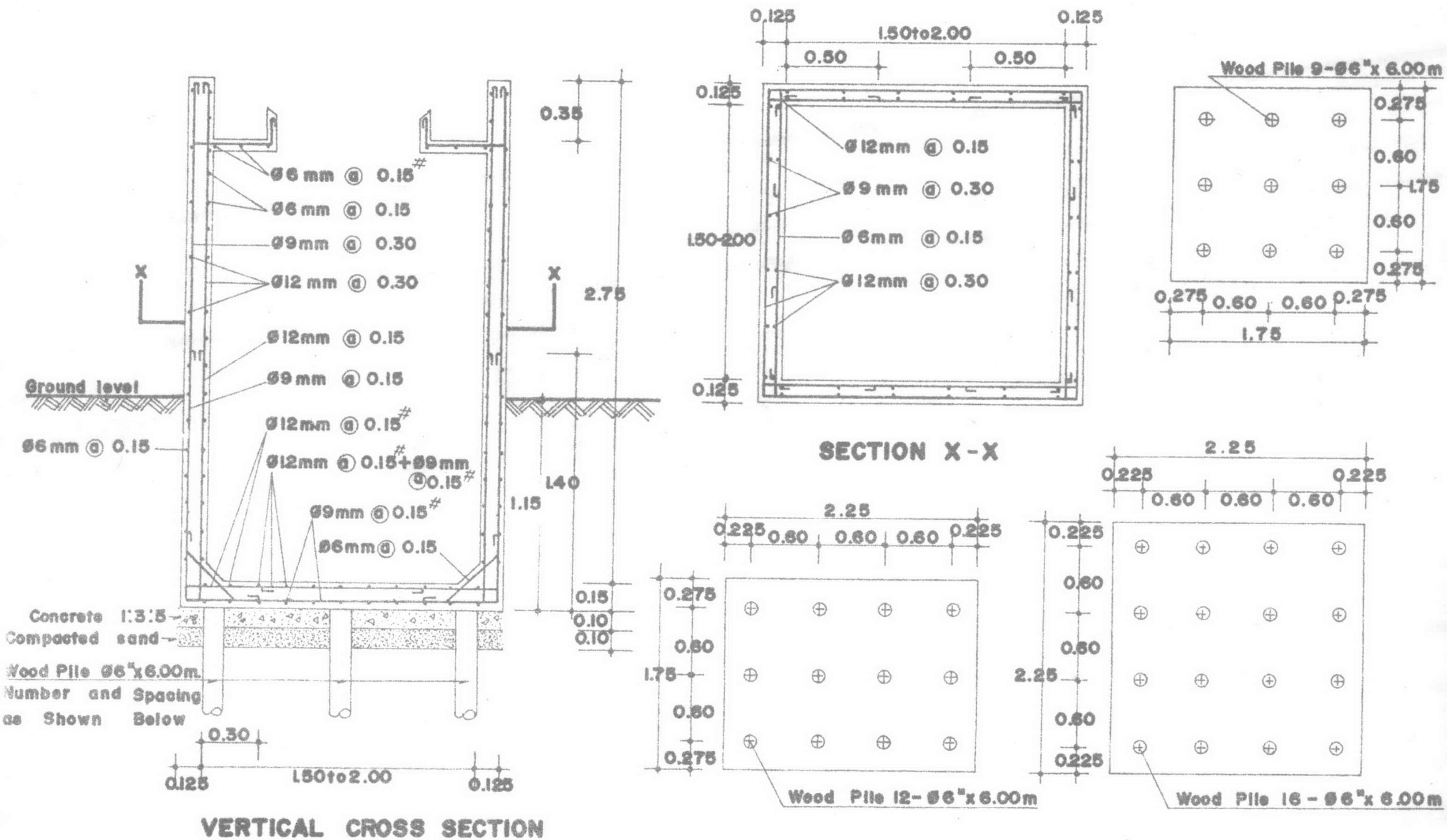


Fig. 33 STRUCTURAL DETAILS OF VARIOUS SIZES OF FILTER TANK.

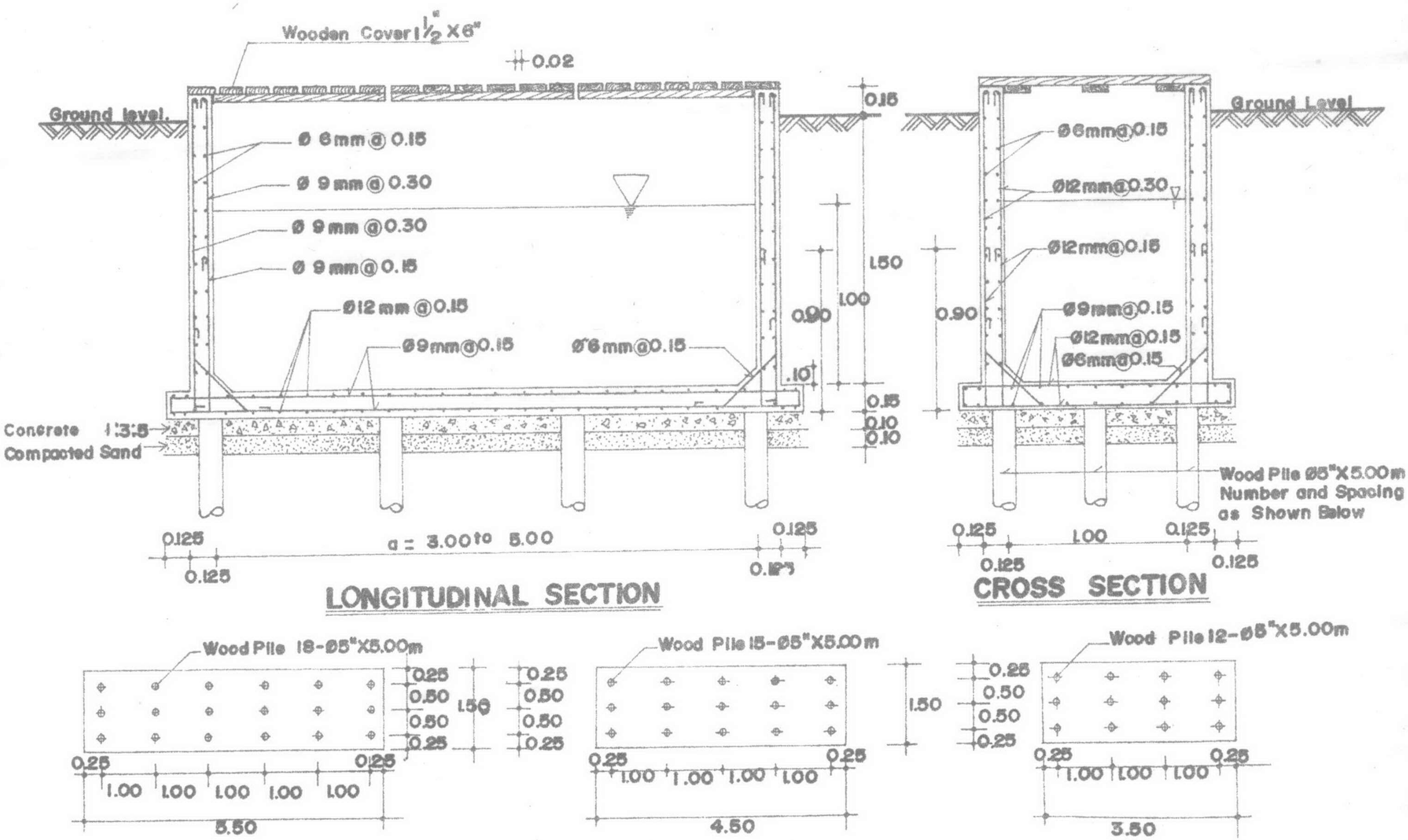


Fig. 34 STRUCTURAL DETAILS OF VARIOUS SIZES OF RAW WATER TANK.

The filter of the service station of 20, 40, 60 and 80 m^3/day capacity is limited to be operated up to 20, 10, 9 and 9 days respectively. After being service cleansing of the filter bed should be done by skimming of about 5 cm from the top of the burnt rice husk layer and the refilling of new burnt rice husk layer of the same quantity should be done after skimming. The duration of cleansing should be less than 1 hour,during the cleansing period the water supply should be used for car washing instead of the filtered water. After cleanning the filter, the rechange of the raw water for the whole reclamation system should be necessarily be replaced by the water supply before re-starting the filter operation.

Comparison of the Existing Systems and the Reclamation System

One way of reflecting in economy studies the comparison of estimated disbursements for alternative systems of washwater supply is to compare the alternatives based upon the equivalent uniform annual series of payment or annual cost, using the minimum attractive rate of return as the interest rate. The interest rate used in conversions for economy studies should be the rate of return required to justify an investment.

From the comparison of the alternative systems in this analysis, some essential specific assumptions are as follows:

1. The receipts of all alternative systems are assumed to be equal and will not be affected by the choices among the alternatives.

2. All salvage values are assumed to be negligible. and

3. The replacement assets will repeat the costs that have been forecasted for the initial asset.

The production costs of water has been divided into variable costs and fixed costs. The variable costs is linearly varied with the out-put and it included the media, water supply, power, lubrication and maintenance costs. The fixed costs included amortization cost, repayment of borrowed capital, which is dependent on the capital cost and labour cost. Labour cost is referred to a fixed cost because it does not vary with the out-put production. In the other way, the production costs might be divided into capital cost and operating cost. In this way the operating cost will include all the mentioned variable costs and the labour cost. In this **analysis** the average **yearly** operating cost was obtained by multiply the average monthly operating cost by 12.

There are two washwater sourses of the existing system, the first one comes from the water supply source and another one is from the ground water source. The only differences between the two existing systems and the reclamation system is that there is no raw water tank and filter tank before the storage tank of the two existing systems and there is no recycle of the washwater back to the raw water tank, Fig.35. Therefore, the system comparison will be considered only on the difference procedures. All cost components has been considered as a function of the design capacity. For the amortization cost mentioned in this book, it has been analysed according to **GRANT** (GRANT & IRESON, 1964).

Cost Analysis of Water Supply Source System

This system has been operated by connecting the water supply pipe from the outside trunk, then it will be pumped to be kept in the storage tank in order to wash the car. After being used, the washwater will be drained directly to the public sewers. The capital cost of this system is the material cost and the installation cost of the piping system.

In the cost analysis, the connected galvanized steel pipe of Ø $1\frac{1}{2}$", with the length of about 60 m and the centrifugal pump

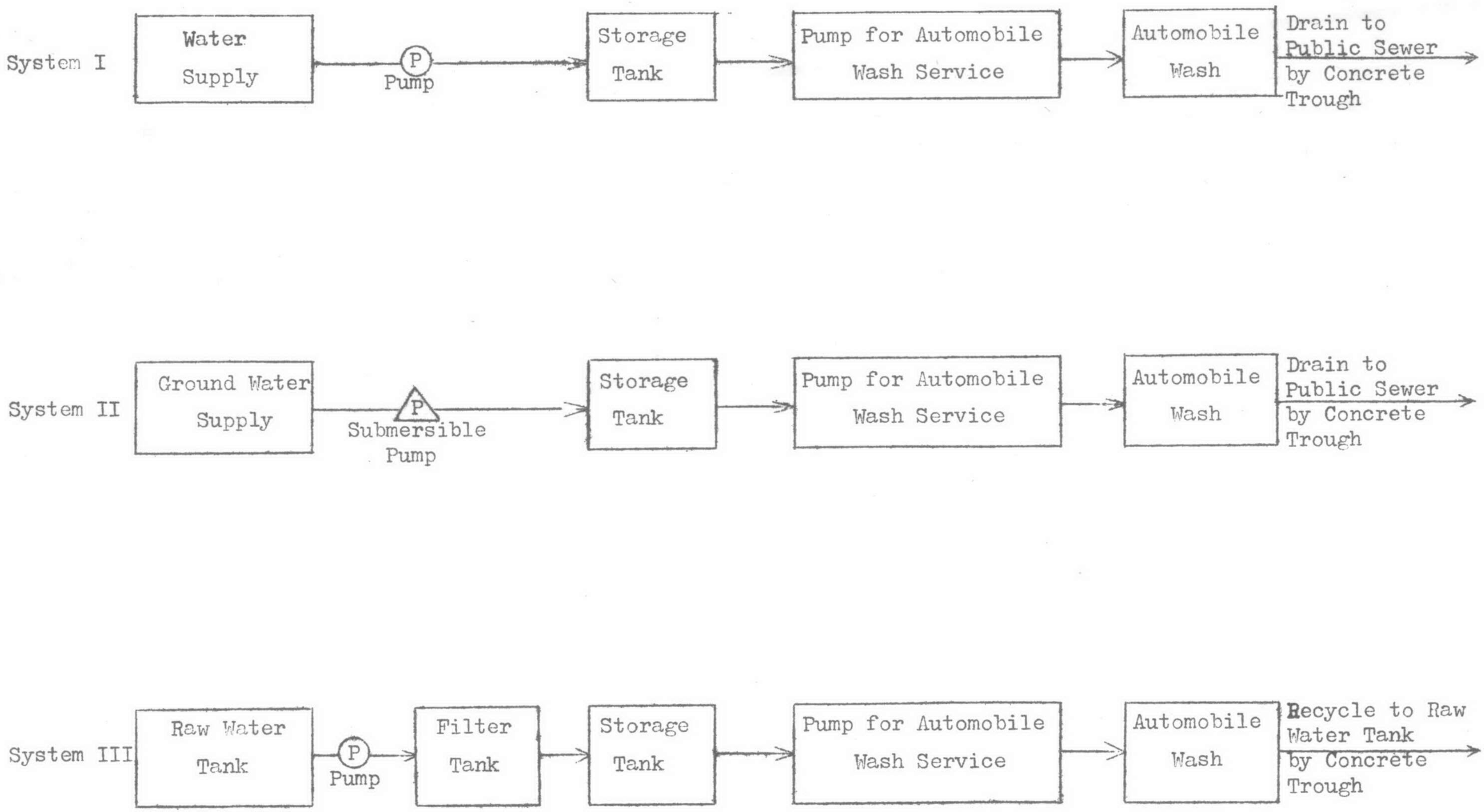


Fig. 35 Configuration of Various Systems to Supply Washwater for Automobile

with the capacity of about 10 m^3/hr, 1 HP are normally being used.

The monthly operating cost, including the water charge, based upon the charging rate of the Metropolitan Water Works Authority; the electric power for pumping cost, based on the charging rate of the Metropolitan Electricity Authority (MEA), for the small industry; the lubrication cost, about 1 baht each lubrication, 5 times a month; and the estimated maintenance cost, which the annual value approximately 4% of the capital cost. This system, the average useful life of the service should be 10 years and the minimum attractive rate of return 8%.

Cost Analysis of Ground Water System

This system, the water is pumped from the well and then it will be kept in the storage tank. After being used as car washing, the washwater will be drained into the public sewers the same as the previous mentioned system.

Since the depth of the wells depends on the sites to be drilled. However, mostly in Bangkok, the depth of the wells is in the range of 100 m to 200 m (PHIANCHAROEN, 1974). Therefore, the cost analysis of this system will be rely on the depth of 100, 150 and 200 m respectively. The capital cost of this system is the sum of the average well construction cost for the typical of Ø 4" well with 100, 150 and 200 m deep respectively. This cost includes the drilling cost, material cost (casing, screen pipe, gravel pack etc.), grouting and casing sealing cost, well development cost and also the submersible pump of 10 m^3/hr, 3 HP including the installation cost. These costs, it will be estimated mostly by the well drilling contractor into one total cost (without specifying any item). All the capital costs of this system in the cost analysis are average value from which are collected by inquiry making from many well drilling contractors and some from the official departments involved.

The monthly operating cost of this system is also consist of the electric power for pumping cost, lubrication cost (the same as the previous mentioned one) and the maintenance cost which the annual value is approximately 1% of the capital cost.

The recommended average useful service life of this system should be about 5 years with the minimum attractive rate of return 8% as well.

Cost Analysis of the Reclamation System

This system is the recycle system of the washwater being used. Beginning with the raw water tank which collects the used washwater. After being stored in the raw water tank, the washed water will be pumped through the filter tank and then collected in the storage tank for automobile-washing purpose. After being used, the water will recycle back to the raw water tank to begin the cycle again.

The capital cost of this system is, again, consisted of the material cost and the installation cost. It means that the capital cost will be comprised of the piping system cost, since it acquires the water supply as a stand by source during cleansing the filter bed; the cost of the pipeline and underdrainage system; the cost of gravel; the rental fee of the truck for transportation of the burnt rice husk from the rice mill; the raw water and filter tank costs; and the costs of two centrifugal pumps of each about 5 m^3/hr, 0.5 HP. These two pumps will be alternately used.

The monthly operating cost comprises of the water charge, media cost, electric power cost for pumping, lubrication cost, maintenance cost and labour cost. The annual maintenance cost is approximately 1% of the capital cost. The useful service life of the concrete tank of this system is assumed to be about 30 years, the service life of the piping system, pump and underdrain pipe is about 10 years and as the same as the previous mentioned system the minimum attractive rate of return is at 8% as well.

Table 16 illustrates the typical capital cost components of various systems. Table 17 shows the monthly operating and maintenance cost components of various systems. Both tables illustrated with various symbols as follows :

R = Reclamation System

G_{100} = deep well of 100 m depth

G_{150} = deep well of 150 m depth

G_{200} = deep well of 200 m depth

W = Water Supply System

The costs tabulated in these two tables will be used to determine the differences of each system in the terms of the annual cost of each system at the range of the capacity from 20 to 80 m^3/day, the total unit production cost of each system for various capacities as mentioned and the determination of the percentage of the total unit production cost of the other systems which is much higher value than that of the Reclamation System.

Sensitivity Analysis and Providing the Guide Cost of the Reclamation System

Sensitivity analysis is the method to check whether a change in any variable would significantly affect the final production cost of the water or not, or it will affect the final cost to change into some other values. These values will be the guide line in estimating the future production cost of the system more accurately.

Table 16 Typical Capital Cost Components of Various Systems.

Type of System	Capacities, m^3/day — Cost Item, ฿	20	40	60	80	Av. Useful life, year
R	- Piping system for Water supply	2,700	2,700	2,700	2,700	10
	- Raw water tank	11,600	11,600	14,200	16,950	30
	- Filter tank	12,050	12,050	14,000	16,350	30
	- Pump 0.5 HP (2 pumps)	6,000	6,000	6,000	6,000	10
	- Pipeline and underdrain	2,750	2,750	2,750	3,000	10
	- Gravel	750	750	1,000	1,350	---
	- Media BRH.	120	120	160	215	---
	Total Capital Cost	35,970	35,970	40,810	46,565	
	Investment at each end of the 10th year	11,450	11,450	11,450	11,700	
G_{100}	- ∅ 4"- 100 m depth, well construction cost include submersible pump 3 HP	70,000	70,000	70,000	70,000	5
G_{150}	- ∅ 4"- 150 m depth, well construction cost include submersible pump 3 HP	80,000	80,000	80,000	80,000	5
G_{200}	- ∅ 4"- 200 m depth, well construction cost include submersible pump 3 HP	110,000	110,000	110,000	110,000	5
W	- Piping system	2,700	2,700	2,700	2,700	10
	- Pump 1 HP	5,700	5,700	5,700	5,700	10
	Total Capital Cost	8,400	8,400	8,400	8,400	

Table 17 Monthly Operating and Maintenance Cost Components of Various Systems.

Type of System	Capacities, m^3/day / Cost Item, ฿	20	40	60	80	Remark
R	- Water supply	15	50	95	125	Variable cost
	- Media - change	15	25	35	45	
	- Electric power for pump	100	175	195	195	
	- Lubrication	5	5	5	5	
	- Maintenance	30	30	35	40	
	- Labour (for cleansing)	200	200	200	200	- Fixed cost
	Total O & M Cost	365	485	565	610	
G_{100}	- Electric power for pump	150	280	410	535	Variable cost
	- Lubrication	5	5	5	5	
	- Maintenance	60	60	60	60	
	Total O & M Cost	215	345	475	600	
G_{150}	- Electric power for pump	150	280	410	535	Variable cost
	- Lubrication	5	5	5	5	
	- Maintenance	65	65	65	65	
	Total O & M Cost	220	350	480	605	
G_{200}	- Electric power for pump	150	280	410	535	Variable cost
	- Lubrication	5	5	5	5	
	- Maintenance	90	90	90	90	
	Total O & M Cost	245	375	505	630	
W	- Water supply	1,355	2,855	4,355	5,855	Variable cost
	- Electric power for pump	65	110	150	195	
	- Lubrication	5	5	5	5	
	- Maintenance	30	30	30	30	
	Total O & M Cost	1,455	3,000	4,540	6,085	

Four parameters to be carried out for comparison are :

i) Effect of the service life of the equipment on the unit production cost.

ii) Effect of the percentage of operation on the unit production cost.

iii) Effect of the maintenance cost on the unit production cost.

iv) Effect of the interest rate on the unit production cost.

Besides, the break-even studies has also been used for determination of what percentage of the capacity (the out-put percentage) would be required to cover the given costs and the assumed water cost.

The results of the mentioned analysis will show us how much the unit production cost would be at any conditions. Also on that condition it will indicate whether the unit production cost will satisfy the requirement or not. On the other hand, it will indicate whether the utilization of this washwater supply will compensate with the expenditure or not.

Results and Discussion

The results of any costs obtained from the calculations, which sample of calculation shown in Appendix B. For the comparison of the alternative systems, the annual cost and the total unit production cost of the 4 capacities, 20 - 80 m^3/day, of each system has been shown in Table 18, Fig. 36 and Fig. 37. The comparison of the percentage of the total unit production cost of any other system which has more value than the Reclamation

System has also been shown in Table 18 and Fig. 38.

From the economic point of view, we can choose the suitable system and the capacity at any location from Table 19, "Selection of System".

The results on the comparison of the existing systems and the Reclamation System can be summarized as follows :

1) The annual cost of the system is directly varied to the capacity to be produced. It was appeared that the annual cost of the Reclamation System is less than either the ground water source system or the water supply source system.

The water supply source system, the annual cost is varied to the capacity at the rate which is higher than the other two systems. At the range of 20 - 34 m^3/day, the annual cost of this system is lower than the annual cost of the ground water source system and it will be higher at the range of 34 - 80 m^3/ day.

The annual cost of each system; the Reclamation System, the ground water source system of 100, 150 and 200 m deep well, and the water supply system for 4 capacities ranges between 8,265 - 12,161 Baht/annum, 20,112 - 24,732 Baht/annum, 22,677 - 27,297 Baht/annum, 30,491 - 35,111 Baht/annum and 18,712 - 74,272 Baht per annum respectively as shown in Table 18 and Fig.36.

2) The total unit production cost, for all capacities, of the Reclamation System and the ground water source system will decrease when the design capacity is increased. But for the water supply source system, the total unit production cost is rather constant. In fact the total unit production cost of the Reclamation System is obviously the less one. At the capacity of 20-34 m^3/day, the cost of the water supply source system is lower than the ground water source system, but at the range of 34-80 m^3/day is much higher than the ground water

source system.

The total unit production cost of the Reclamation System, the ground water source system at 100,150 and 200 m deep well, and the water supply source system for 4 capacities is in the range from 1.15-0.42 Baht/m^3, 2.79-0.86 Baht/m^3 3.15-0.95 Baht/m^3, 4.24-1.22 Baht/m^3 and 2.60-2.58 Baht/m^3 respectively as shown in Table 18 and Fig.37.

3) For the percentage of the total unit production cost which higher than that of Reclamation System of the ground water source system. From Table 18 and Fig.38, the more the capacities the lower the percentage of the cost. On the other hand for the water supply source system the more the capacities used the higher the percentage of the cost.

The percentage of cost higher than that of Reclamation System for the ground water source system of the 100,150 and 200 m deep well and also the water supply source system for 4 capacities ranges of 104.76-142.61%, 126.19-173.91%, 190.48-268.70% and 126.09-514.29% respectively as shown in Table 18 and Fig.38.

4) The results of the comparison of the 3 systems. It is obvious that at the range of 20-80 m^3/day capacities and at the depth of 100 to 200 m deep well of the ground water source system. The Reclamation System is somewhat better than the other 2 systems as shown in Table 19.

5) The comparison between the water supply source system and the ground water source system, Table 19, shows that:

i) At the depth of 100 m deep well:

- for the capacity of 20-22 m^3/day, the water supply source system is better than the ground water source system;

Table 18 Annual Cost and Unit Production Cost Based on Total Cost of Various Systems

Capacity m^3/day	Type of System / Item		R	G_{100}	G_{150}	G_{200}	W
20	Annual Cost	฿	8,265	20,112	22,677	30,491	18,712
	Unit Production Cost	฿/m^3	1.15	2.79	3.15	4.24	2.60
	Unit Production Cost Higher than R	%	-	142.61	173.91	268.70	126.09
40	Annual Cost	฿	9,705	21,672	24,237	32,051	37,252
	Unit Production Cost	฿/m^3	0.67	1.51	1.68	2.23	2.59
	Unit Production Cost Higher than R	%	-	125.37	150.75	232.84	286.57
60	Annual Cost	฿	11,094	23,232	25,797	33,611	55,732
	Unit Production Cost	฿/m^3	0.51	1.08	1.19	1.56	2.58
	Unit Production Cost Higher than R	%	-	111.76	133.33	205.88	405.88
80	Annual Cost	฿	12,161	24,732	27,297	35,111	74,272
	Unit Production Cost	฿/m^3	0.42	0.86	0.95	1.22	2.58
	Unit Production Cost Higher than R	%	-	104.76	126.19	190.48	514.29

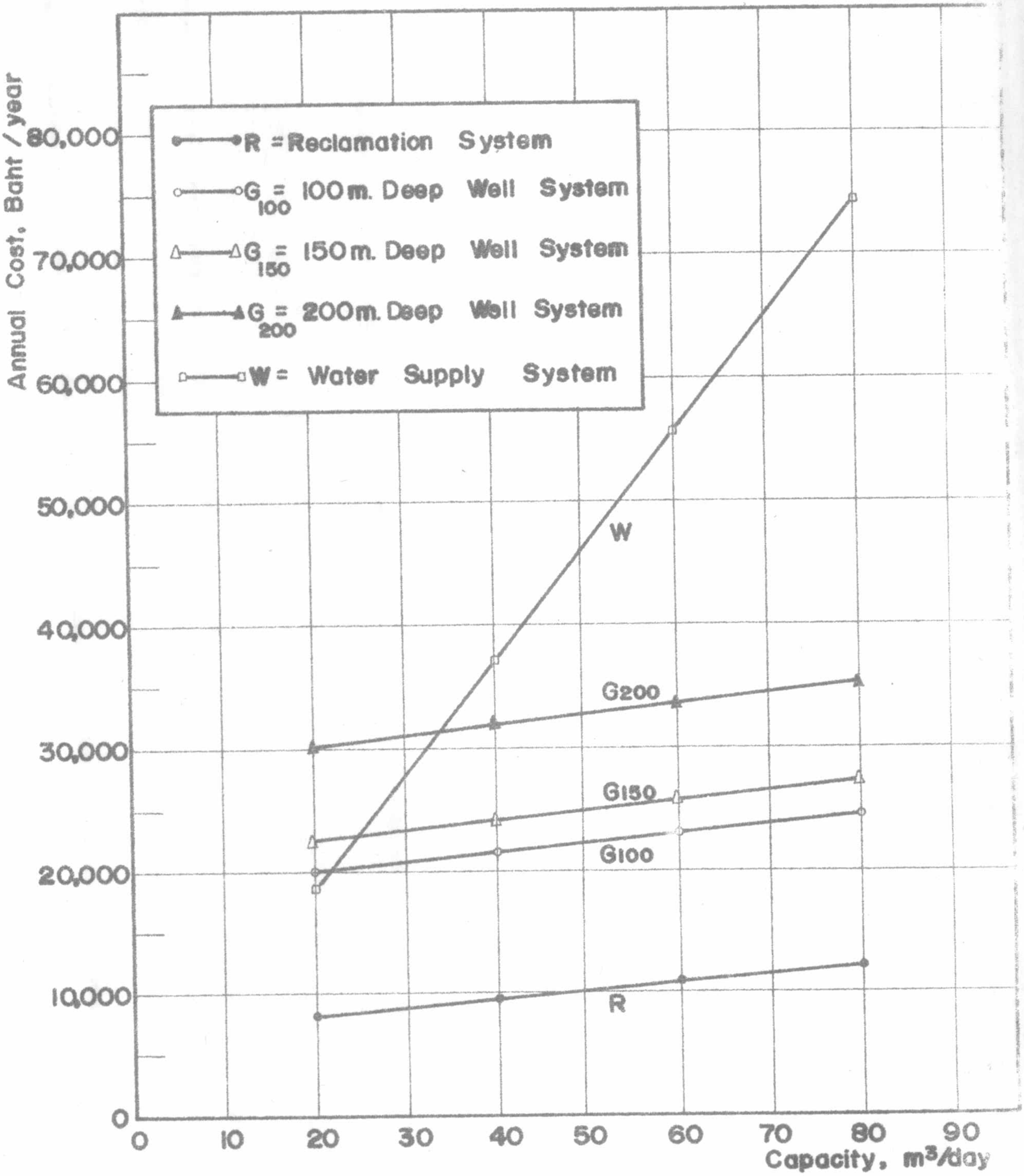


Fig. 36 Annual Cost of each System at Various Capacities.

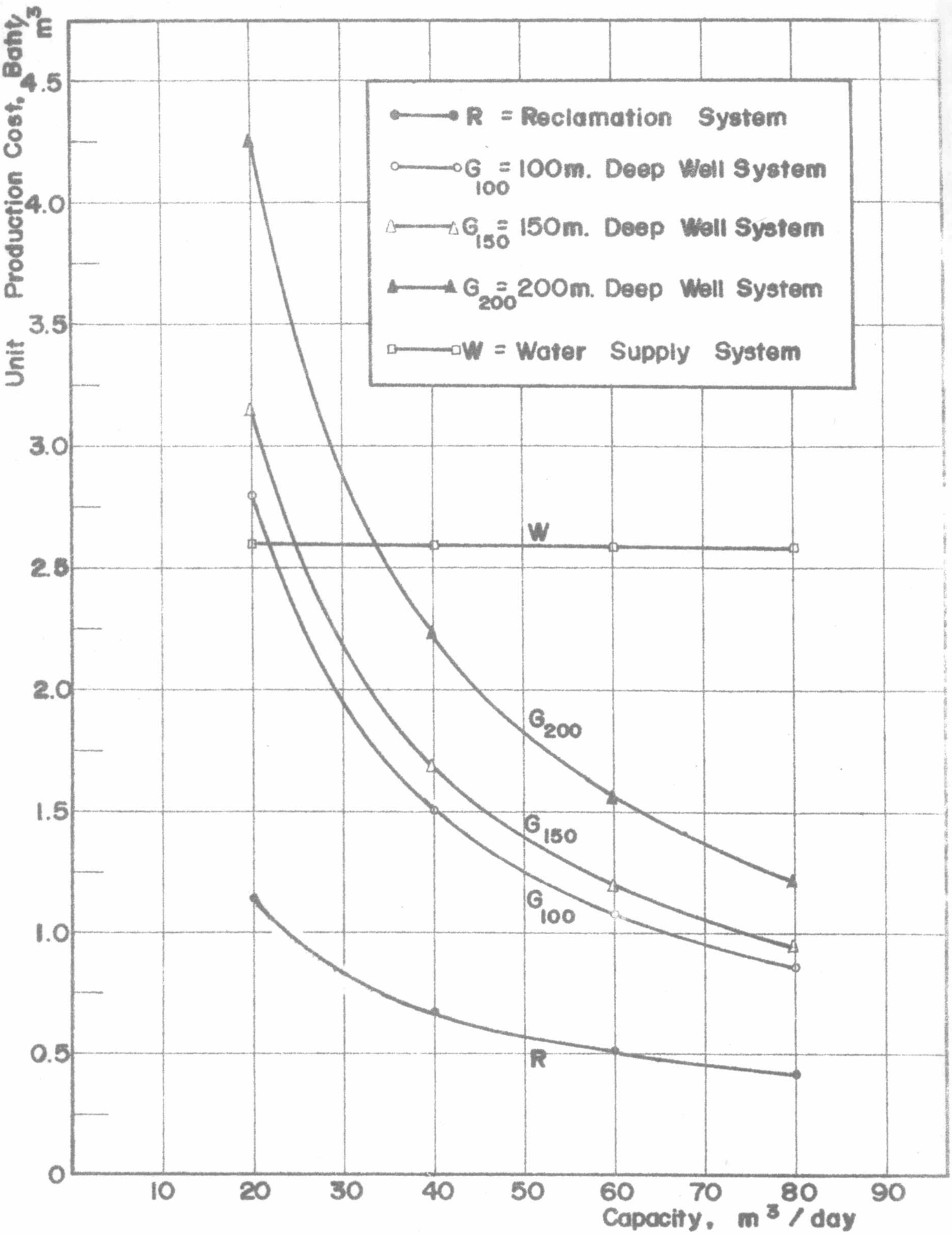


Fig. 37 Total Unit Production Cost of each System at Various Capacities.

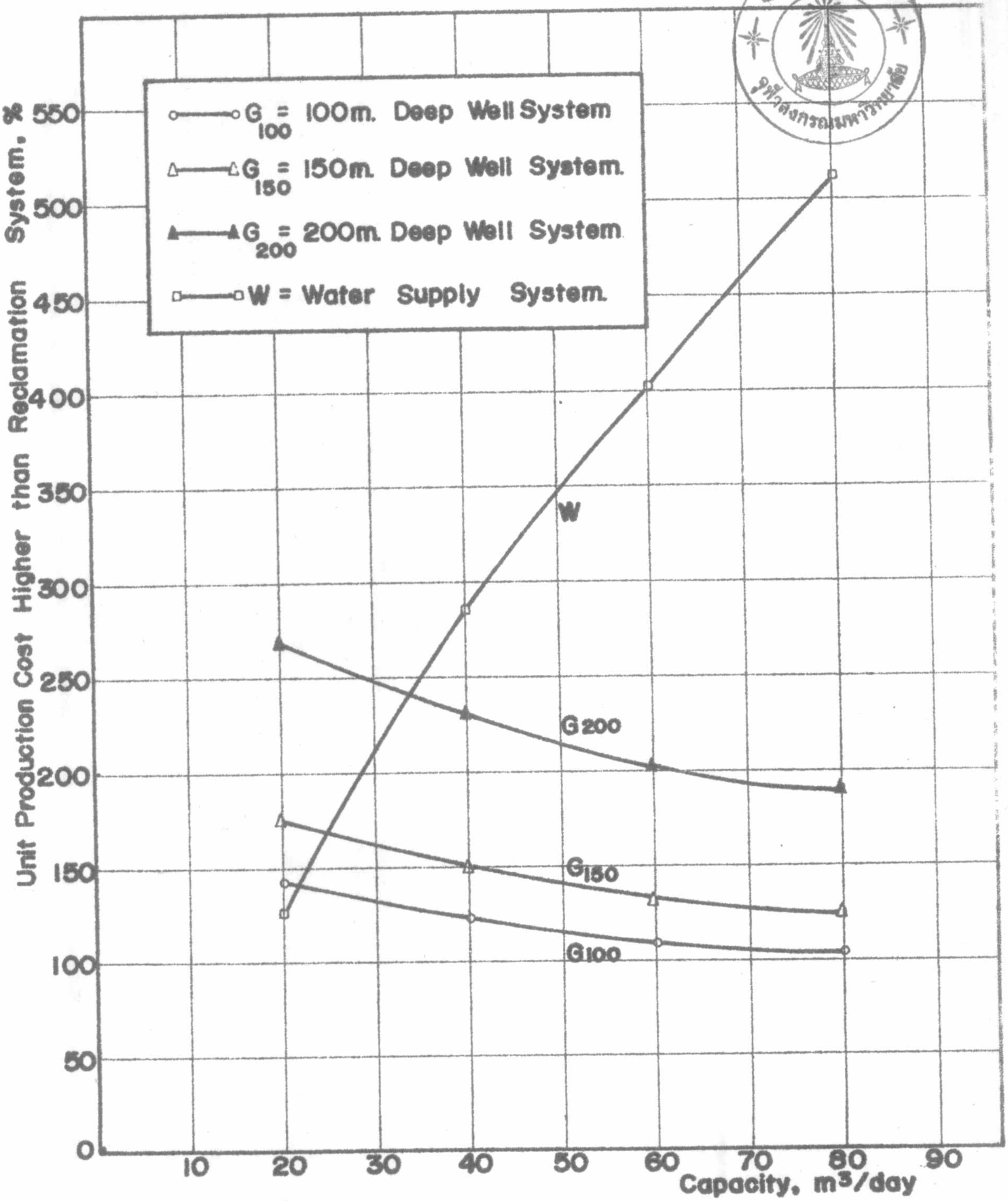
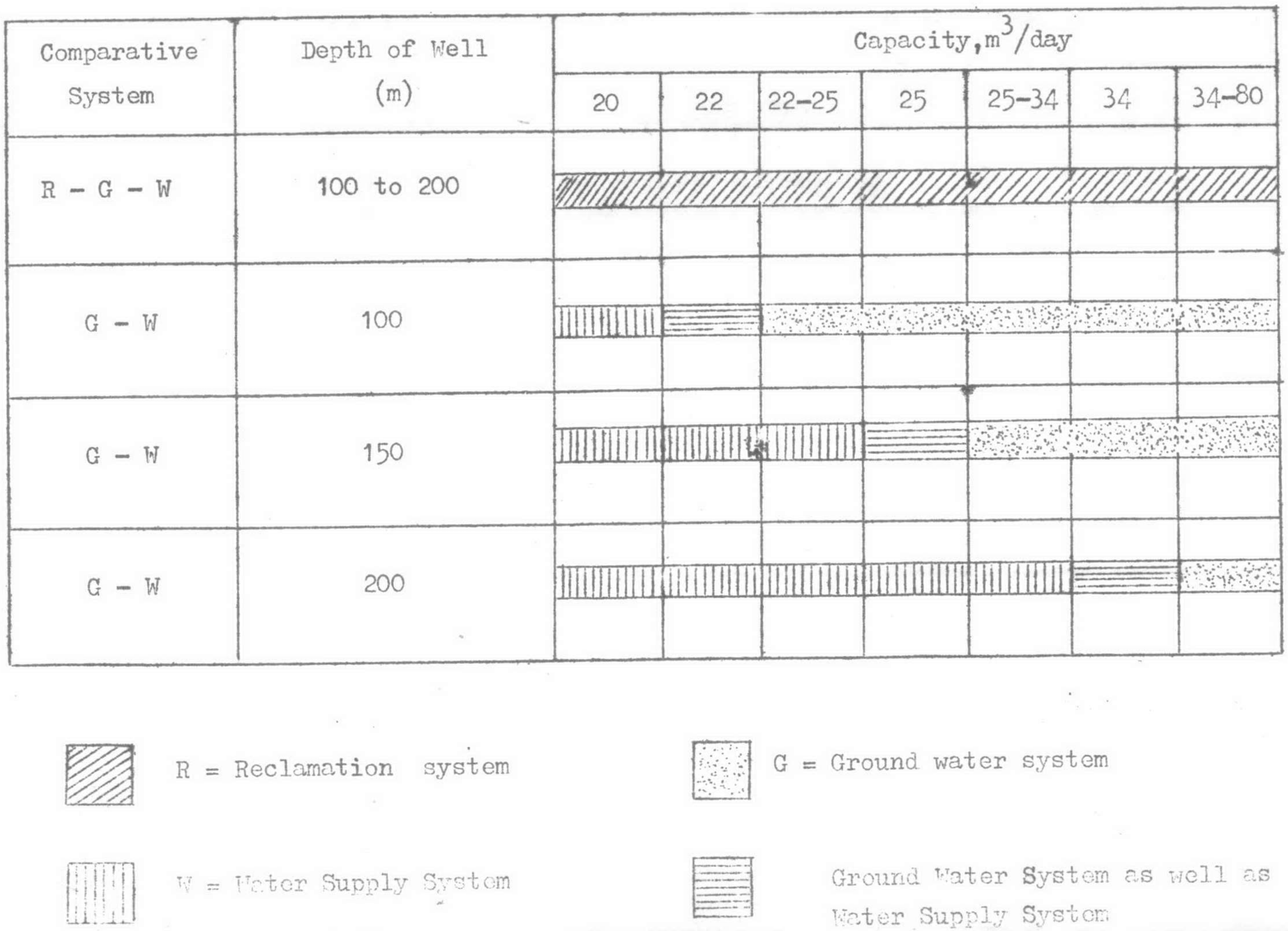


Fig. 38 Total Unit Production Cost Higher than Reclamation System of each System at Various Capacities.

Table 19 Selection of System Based on Unit Production Cost at Various Capacities



- for the capacity of 22 m^3/day, the water supply source system is as the same as the ground water source system; and

- for the capacity of 22-80 m^3/day, the ground water source system is better than the water supply source system.

ii) At the depth of 150 m deep well:

- the water supply source system is better than the ground water source system at 20-25 m^3/day capacity;

- the water supply source system is as the same as the ground water source system at 25 m^3/day capacity;and

- the ground water source system is better than the water supply source system at 25-80 m^3/day.

iii) At the depth of 200 m deep well:

- the water supply source system is better at 20-34 m^3/day;

- the two systems are as the same as each other at 34 m^3/day; and

- the ground water source system is better at 34-80 m^3/day.

The results from sensitivity analysis and the cost providing guideline of the Reclamation System is illustrated in Tables 20 to 26 and Figs. 39 to 45 and it will be summarized as follows:

1) The changes in service life of the equipment, the production as a percentage of operation, the maintenance cost, the interest rate and the production as a percentage of the out-put capacity will significantly produce changes in total unit production costs. It appeared that the most important variable affected the production cost was the production as a percentage of operation.

2) The total unit production cost of the Reclamation System from the capacity of 20 to 80 m^3/day will decrease when the service life is increase. At the capacity of 20,40,60 and 80 m^3/day, the service life is 5-30 years, the total unit production cost of this system will be 1.15-1.86 Baht/m^3, 0.67-1.03 Baht/m^3, 0.51-0.79 Baht/m^3 and 0.42-0.66 Baht/m^3 respectively as shown in Table 20 and Fig. 39.

Resulting from the experiment, though the service life of the equipment is only 5 years for the Reclamation System of the 4 capacities, the total unit production cost is still lower than that of the ground water source systems of 3 depths and that of the water supply source system as mentioned in the previous section as well.

3) The total unit production cost of the Reclamation System of 20-80 m^3/day will decrease when the percentage of operation is increase. At 20-100% of operation of 20,40,60 and 80 m^3/day, these values will be in the range of 1.15-4.64 Baht/m^3, 0.67-2.42 Baht/m^3, 0.51-1.76 Baht/m^3 and 0.42-1.43 Baht/m^3 respectively as shown in Table 21 and Fig. 40.

Besides, at about 40% of operation for the 4 capacities, the total unit production cost is still less than that of the ground water source system and the water supply source system. But if it is only 20% of operation; at 20 m^3/day the total unit production cost will higher than either the ground water source system or the water supply source system, at 40,60 and 80 m^3/day this cost is still higher than that of the ground water source system but less than that of the water supply source system.

4) The total unit production cost of the Reclamation System at 20-80 m^3/day will increase according to the increased maintenance cost. When the annual maintenance cost is 1-5% of the capital cost at 20,40,60 and 80 m^3/day, these costs will

be in the range of 1.15 - 1.35 Baht/m^3, 0.67 - 0.77 Baht/m^3, 0.51 - 0.59 Baht/m^3 and 0.42 - 0.49 Baht/m^3 respectively as illustrated in Table 22 and Fig. 41.

Although the annual maintenance cost will be about 5% of the capital cost, still the total unit production cost is lower than that of the ground water source system and the water supply source system as well.

5) The total unit production cost of the Reclamation System at 20 - 80 m^3/day will increase linearly according to the increasing of the interest rate charge. At about 4 - 12% interest rate of 20, 40, 60 and 80 m^3/day, the total unit production cost will be in the range of 1.00 - 1.31 Baht/m^3, 0.60 - 0.76 Baht/m^3, 0.46 - 0.58 Baht/m^3 and 0.37 - 0.48 Baht/m^3 respectively as shown in Table 23 and Fig. 42.

Up to 12% interest rate of the 4 capacities, the total unit production cost is still lower than that of either the ground water source system at 3 depths or the water supply source system.

6) The unit production cost based on both the total cost and operating cost of the Reclamation System at 20 - 80 m^3/day will decrease when the percentage of the out-put capacity is increase. At the percentage of the out-put capacity 25 - 100% of 20, 40, 60 and 80 m^3/day, the unit production cost based on the total cost will be in the range of 1.15 - 3.77 Baht/m^3, 0.67 - 1.98 Baht/m^3, 0.51 - 1.45 Baht/m^3 and 0.42 - 1.18 Baht/m^3 respectively as shown in Table 24 and Fig. 43.

The unit production cost based on the operating costwhen the percentage of the out-put capacity 25 - 100% of 20, 40, 60 and 80 m^3/day will be in the range of 0.61 - 1.61 Baht/m^3, 0.40 - 0.91 Baht/m^3, 0.31 - 0.65 Baht/m^3 and 0.25 - 0.50 Baht/m^3 respectively as shown in Table 24 and Fig.44.

For the 4 capacities; if the capacity of out-put is only 50%, the total unit production cost is still less than that of either the ground water source system or the water supply source system. But if the capacity of out-put is decreased to 25%; at 20 m^3/day the total unit production cost will higher than the cost of the ground water source system only for the 100 and 150 m deep well and also the cost of the water supply source system, but at 40, 60 and 80 m^3/day the unit production cost will be less than that of the 200 m deep well and also the water supply source system.

7) According to the design for the Reclamation System; the service life of the concrete tank is 30 years, pipeline and pump 10 years, the interest rate of 8%, 100% of operation, the annual maintenance cost of about 1% of the capital cost and at 100% of the out-put capacity. From the previous mentions the unit production cost based on the total cost of 20 - 80 m^3/day capacity will lie upon 0.42 - 1.15 Baht/m^3 and based on the operating cost will be 0.25 - 0.61 Baht/m^3 as shown in Fig.45.

8) On the conditions of 10 years service life, 100% of operation, the annual maintenance cost of about 4% of the capital cost, the interest rate of 8% and 100% capacity of out-put will result the total unit production cost of water supply source system of 20 - 80 m^3/day to be the range of 2.58 - 2.60 ฿/m^3, Table 25.

9) On the conditions of 5 years service life, 100% of operations, the annual maintenance cost 1% of the capital cost, 8% interest rate and 100% of the capacity of out-put. The total unit production cost of the 3 deep wells capacity of 20, 40, 60 and 80 m^3/day will be in the range of 2.79 - 4.24 Baht/m^3, 1.51 - 2.23 Baht/m^3, 1.08 - 1.56 Baht/m^3 and 0.86 - 1.22 Baht/m^3

respectively, Table 25.

10) As mentioned in the item No.7 if there is a change in any variable such as the service life is reduced to be 5 years or the percentage of the operation is 40% or the annual maintenance cost gets higher to 5% of capital cost or the interest rate gets higher to 12% or 50% capacity of out-put. The total unit production cost at 20, 40, 60 and 80 m^3/day will change to be in the range of 1.31 - 2.46 Baht/m^3, 0.76 - 1.33 Baht/m^3, 0.58 - 0.98 Baht/m^3 and 0.48 - 0.80 Baht/m^3 respectively Table 26. Anyway the value at such the conditions above is still less than the value of ground water source system and water supply source system that mentioned in the item No.8 and No.9.

Table 20 **Total Unit Production Cost of Reclamation System at Various Equipment Lifes (i = 8 %)**

Capacity m^3/day	Equipment Life Year	Amortization ฿/month	Operating Cost ฿/month	Total Monthly Cost ฿	Total Unit Production Cost ฿/m^3
20	5	750.75	365	1,115.75	1.86
	10	446.72	365	811.72	1.35
	20	350.31	365	715.31	1.19
	30	323.71	365	688.71	1.15
40	5	750.75	485	1,235.75	1.03
	10	446.72	485	931.72	0.78
	20	350.31	485	835.31	0.70
	30	323.71	485	808.71	0.67
60	5	851.77	565	1,416.77	0.79
	10	506.83	565	1,071.83	0.60
	20	391.39	565	956.39	0.53
	30	359.54	565	924.54	0.51
80	5	971.89	610	1,581.89	0.66
	10	578.30	610	1,188.30	0.50
	20	441.22	610	1,051.22	0.44
	30	403.39	610	1,013.39	0.42

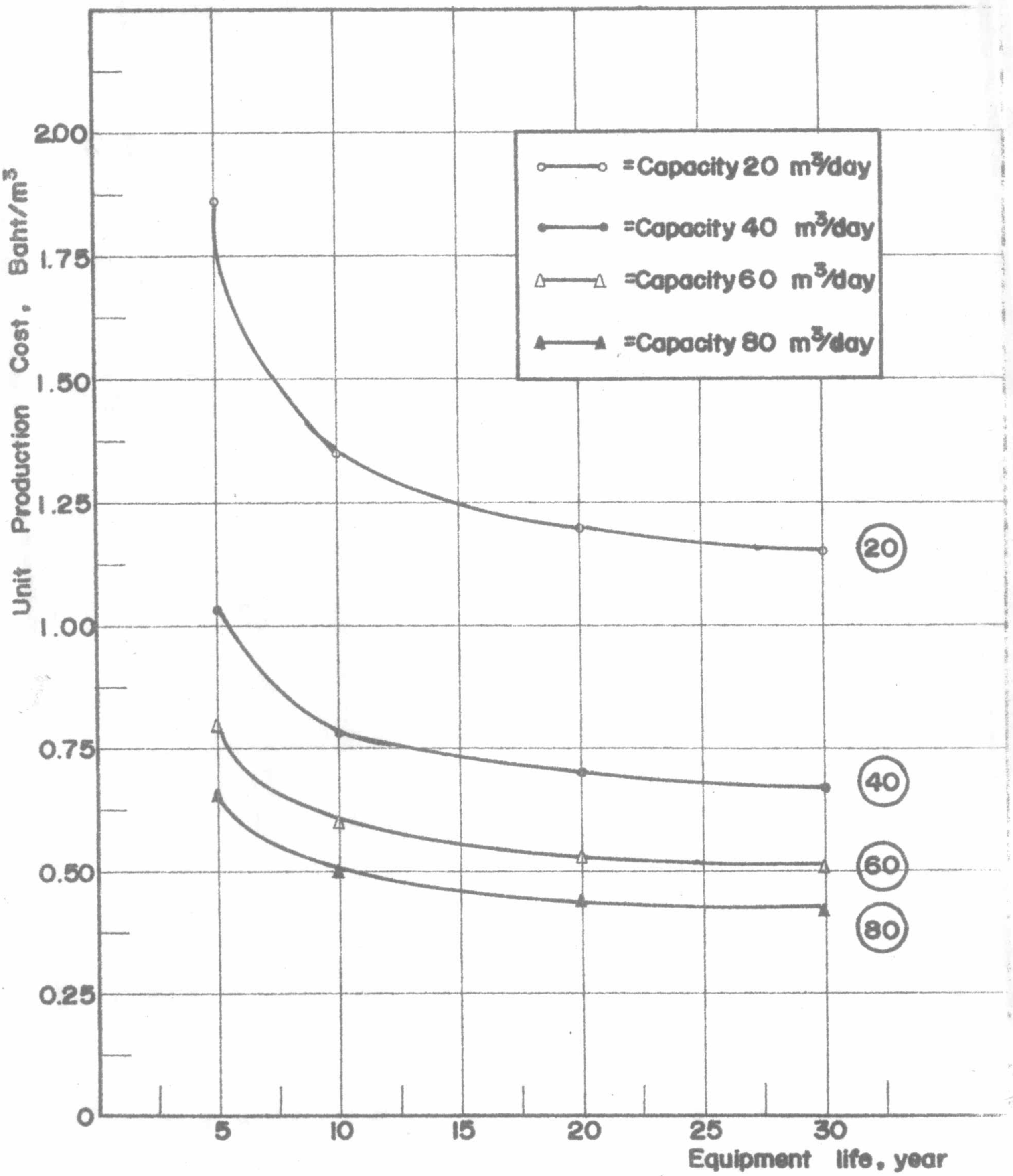


Fig. 39 Total Unit Production Cost of Reclamation System at Various Equipment lifes.

Table 21 Total Unit Production Cost of Reclamation System at Various Percents of Operation (i = 8 %, n = 30 years)

Capacity m^3/day	Percent of Operation	Monthly Fixed Cost ฿/month	Monthly Variable Cost ฿/month	Total Monthly Cost ฿	Monthly Product of Water m^3/month	Total Unit Production Cost ฿/m^3
20	100	523.71	165	688.71	600	1.15
	80	523.71	132	655.71	480	1.37
	60	523.71	99	622.71	360	1.73
	40	523.71	66	589.71	240	2.46
	20	523.71	33	556.71	120	4.64
40	100	523.71	285	808.71	1,200	0.67
	80	523.71	228	751.71	960	0.78
	60	523.71	171	694.71	720	0.96
	40	523.71	114	637.71	480	1.33
	20	523.71	57	580.71	240	2.42
60	100	559.54	365	924.54	1,800	0.51
	80	559.54	292	851.54	1,440	0.59
	60	559.54	219	778.54	1,080	0.72
	40	559.54	146	705.54	720	0.98
	20	559.54	73	632.54	360	1.76
80	100	603.39	410	1,013.39	2,400	0.42
	80	603.39	328	931.39	1,920	0.49
	60	603.39	246	849.39	1,440	0.59
	40	603.39	164	767.39	960	0.80
	20	603.39	82	685.39	480	1.43

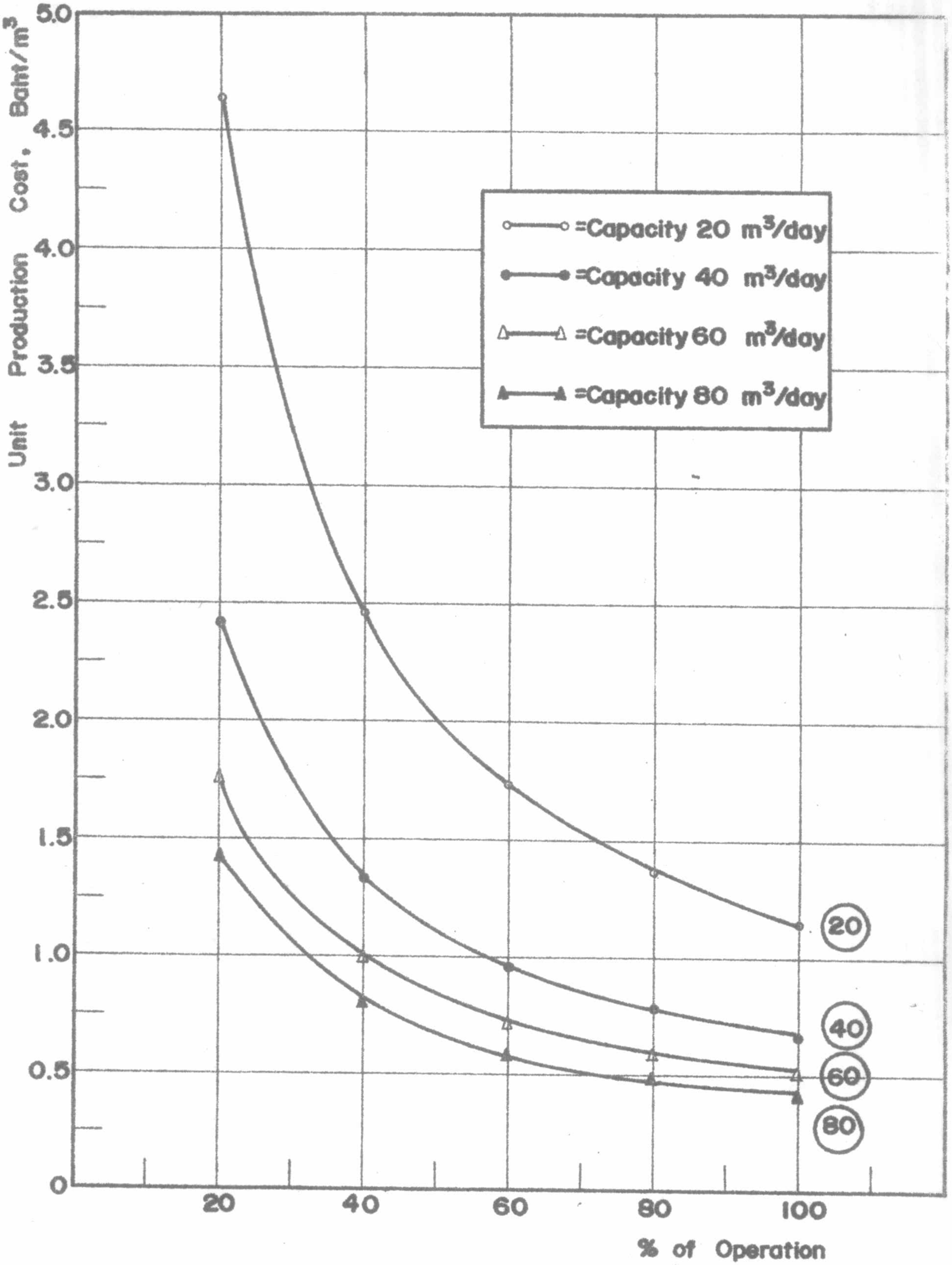


Fig.40 Total Production Cost of Reclamation System at Various Percents of Operation.

Table 22 **Total Unit Production Cost of Reclamation System at Various Maintenance Costs(i = 8%, n = 30 years)**

Capacity m^3/day	**Maintenance** Cost %	Maintenance Cost ฿/month	Cost Without Maintenance ฿/month	Total Monthly Cost ฿	Total Unit Production Cost ฿/m^3
20	1	30	658.71	688.71	1.15
	2	60	658.71	718.71	1.20
	3	90	658.71	748.71	1.25
	4	120	658.71	778.71	1.30
	5	150	658.71	808.71	1.35
40	1	30	778.71	808.71	0.67
	2	60	778.71	838.71	0.70
	3	90	778.71	868.71	0.72
	4	120	778.71	898.71	0.75
	5	150	778.71	928.71	0.77
60	1	35	889.54	924.54	0.51
	2	70	889.54	959.54	0.53
	3	105	889.54	994.54	0.55
	4	140	889.54	1,029.54	0.57
	5	175	889.54	1,064.54	0.59
80	1	40	973.39	1,013.39	0.42
	2	80	973.39	1,053.39	0.44
	3	120	973.39	1,093.39	0.46
	4	160	973.39	1,133.39	0.47
	5	200	973.39	1,173.39	0.49

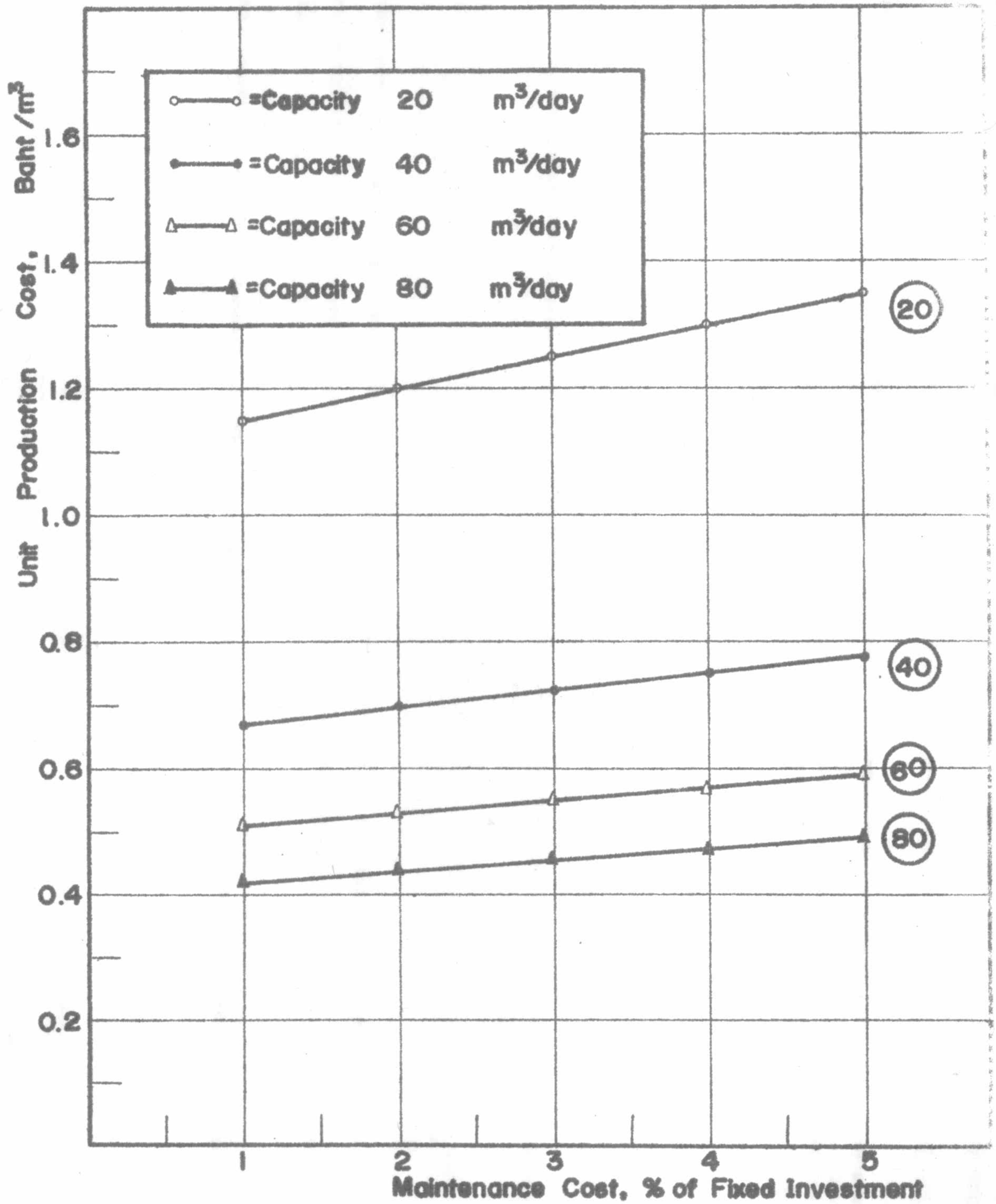


Fig. 41 Total Unit Production Cost of Reclamation System at Various Maintenance Costs.

Table 23 Total Unit Production Cost of Reclamation System at Various Interest Rates (n = 30 years)

Capacity m^3/day	Interest Rate (i) %	Amortization ฿/month	Operating Cost ฿/month	Total Monthly Cost ฿	Total Unit Production Cost ฿/m^3
20	4	236.31	365	601.31	1.00
	6	278.09	365	643.09	1.07
	8	323.71	365	688.71	1.15
	10	372.04	365	737.04	1.23
	12	422.53	365	787.53	1.31
40	4	236.31	485	721.31	0.60
	6	278.09	485	763.09	0.64
	8	323.71	485	808.71	0.67
	10	372.04	485	857.04	0.71
	12	422.53	485	907.53	0.76
60	4	259.63	565	824.63	0.46
	6	307.39	565	872.39	0.48
	8	359.54	565	924.54	0.51
	10	414.82	565	979.82	0.54
	12	472.60	565	1,037.60	0.58
80	4	288.74	610	898.74	0.37
	6	343.55	610	953.55	0.40
	8	403.39	610	1,013.39	0.42
	10	466.88	610	1,076.88	0.45
	12	533.24	610	1,143.24	0.48

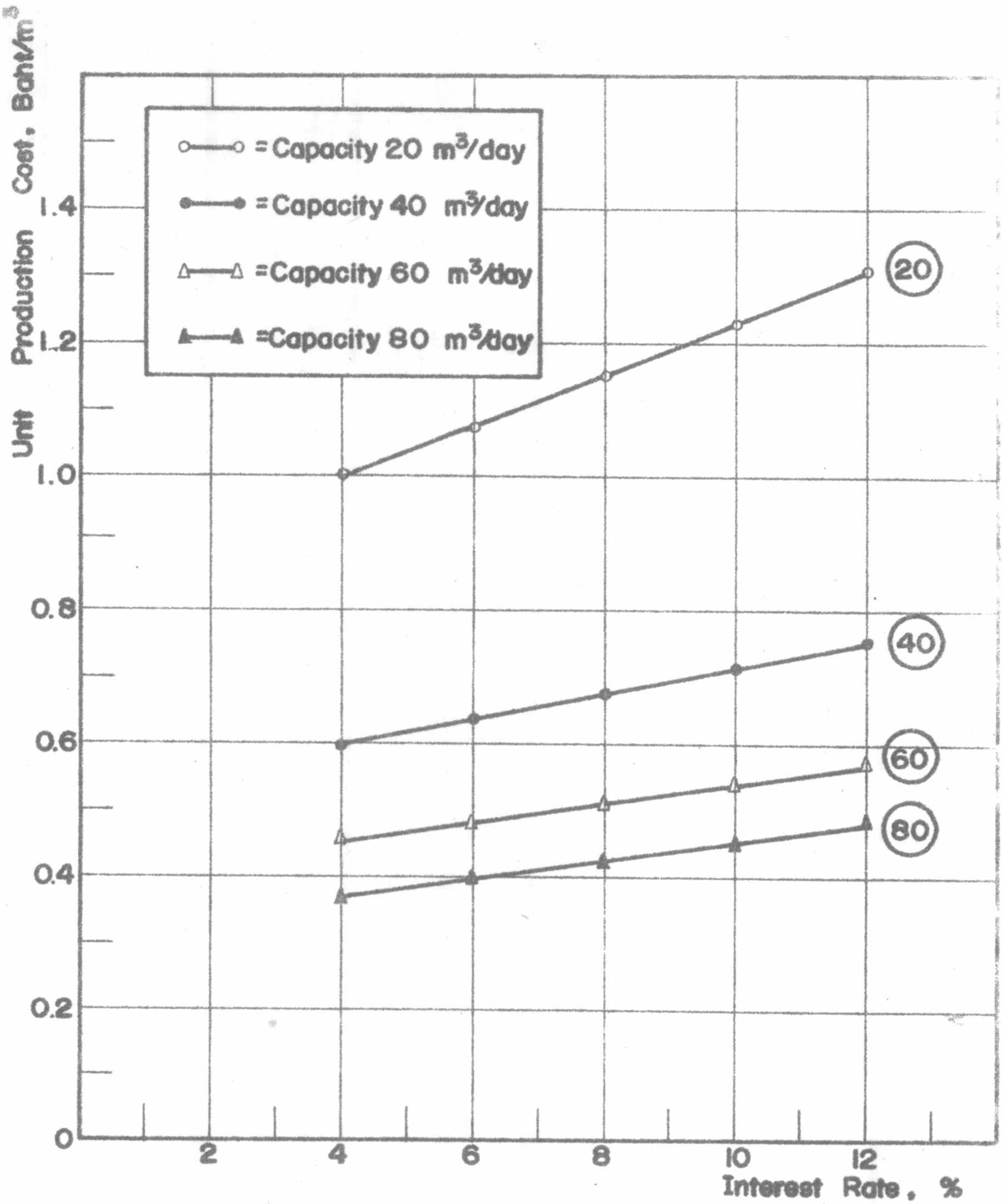


Fig. 42 Total Unit Production Cost of Reclamation System at Various Interest Rates.

Table 24 Unit Production Cost at Break Even Points of Reclamation System

Capacity m^3/day	Break Even (% out-put Capacity)	Total Unit Production Cost ฿/m^3	Operating Unit Production Cost ฿/m^3
20	100	1.15	0.61
	75	1.44	0.72
	50	2.02	0.94
	25	3.77	1.61
40	100	0.67	0.40
	75	0.82	0.46
	50	1.11	0.57
	25	1.98	0.91
60	100	0.51	0.31
	75	0.62	0.35
	50	0.83	0.43
	25	1.45	0.65
80	100	0.42	0.25
	75	0.51	0.28
	50	0.67	0.34
	25	1.18	0.50

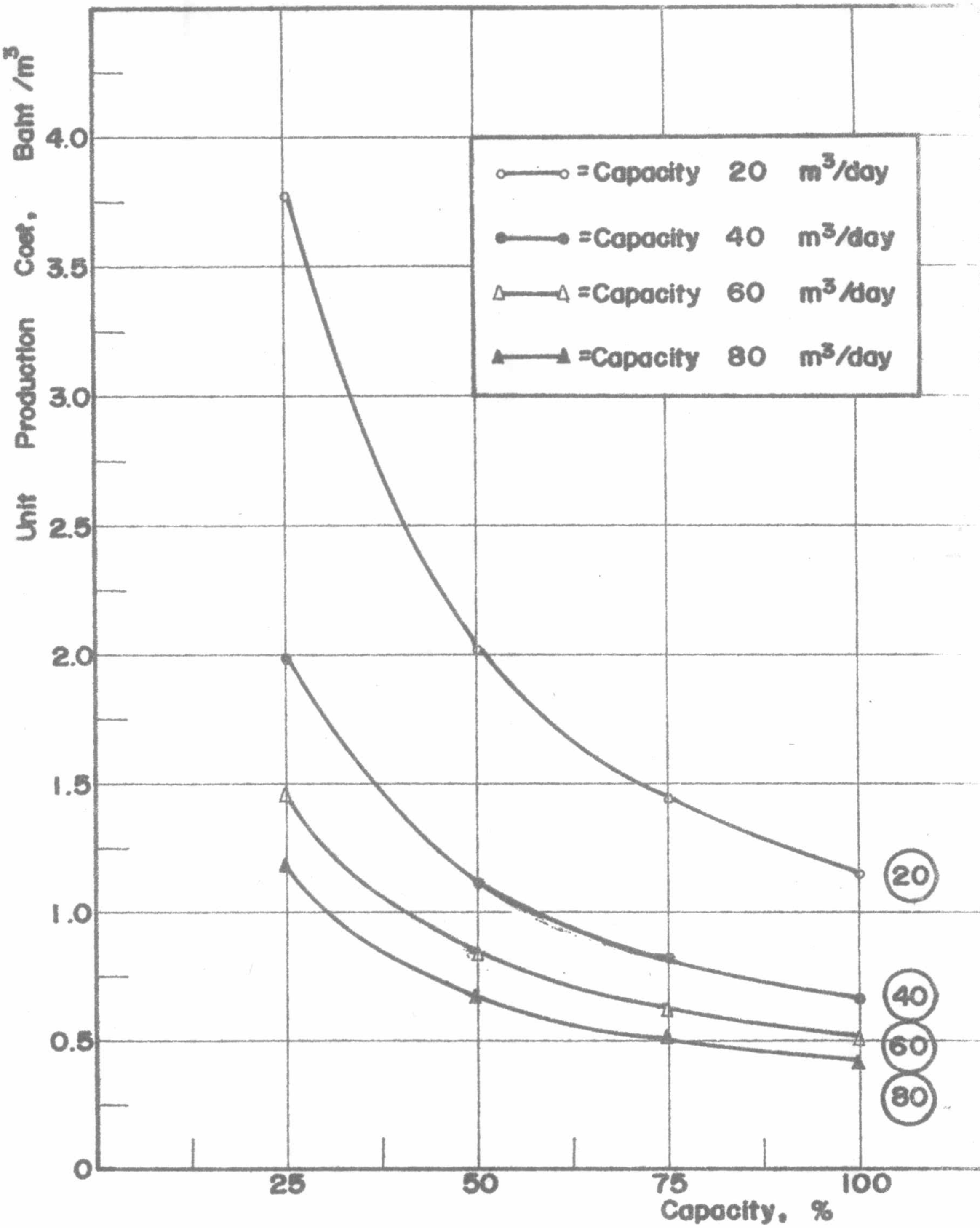


Fig.43 Break Even Chart Based on Total Cost of Reclamation System.

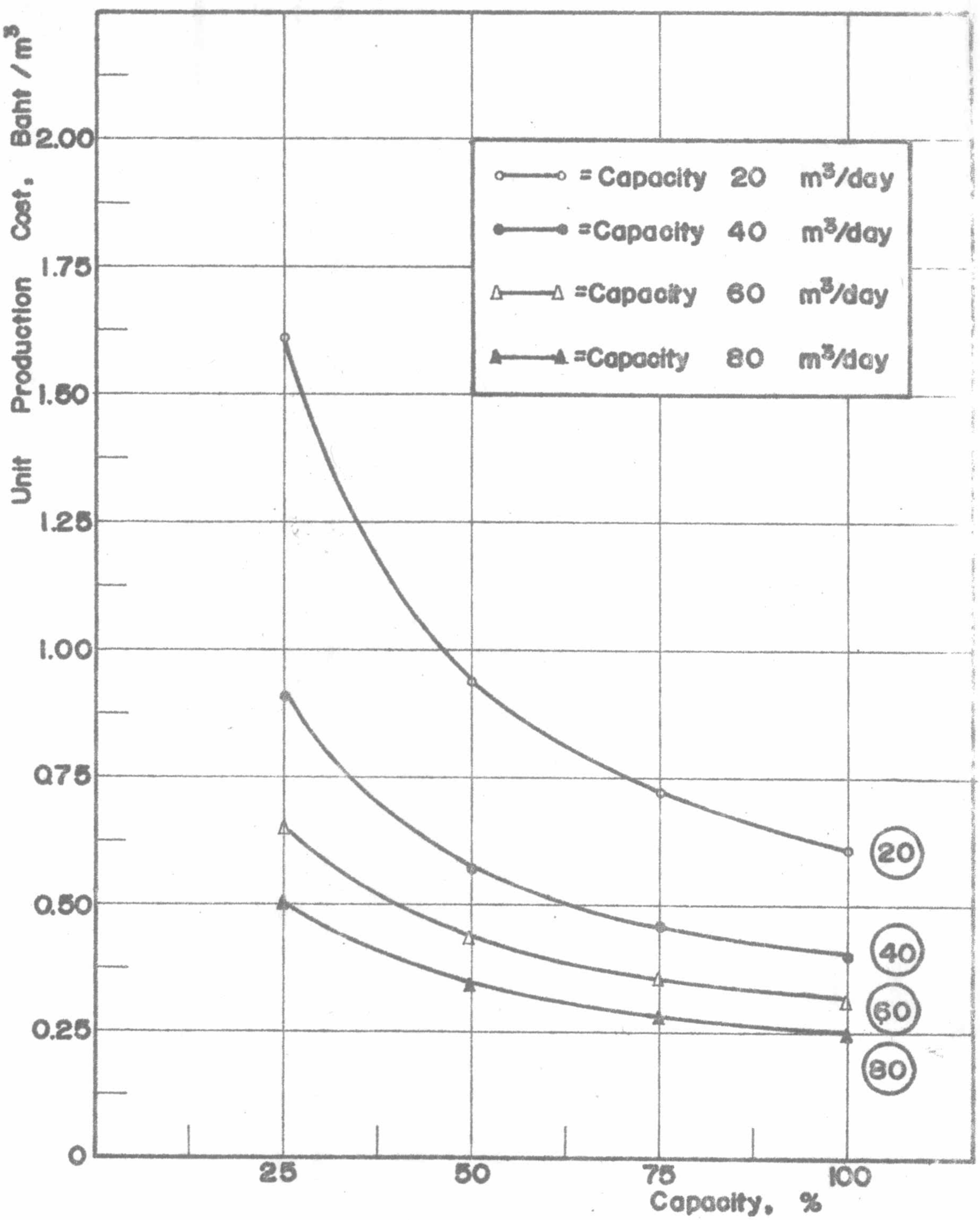


Fig.44 Break Even Chart Based on Operating Cost of Reclamation System.

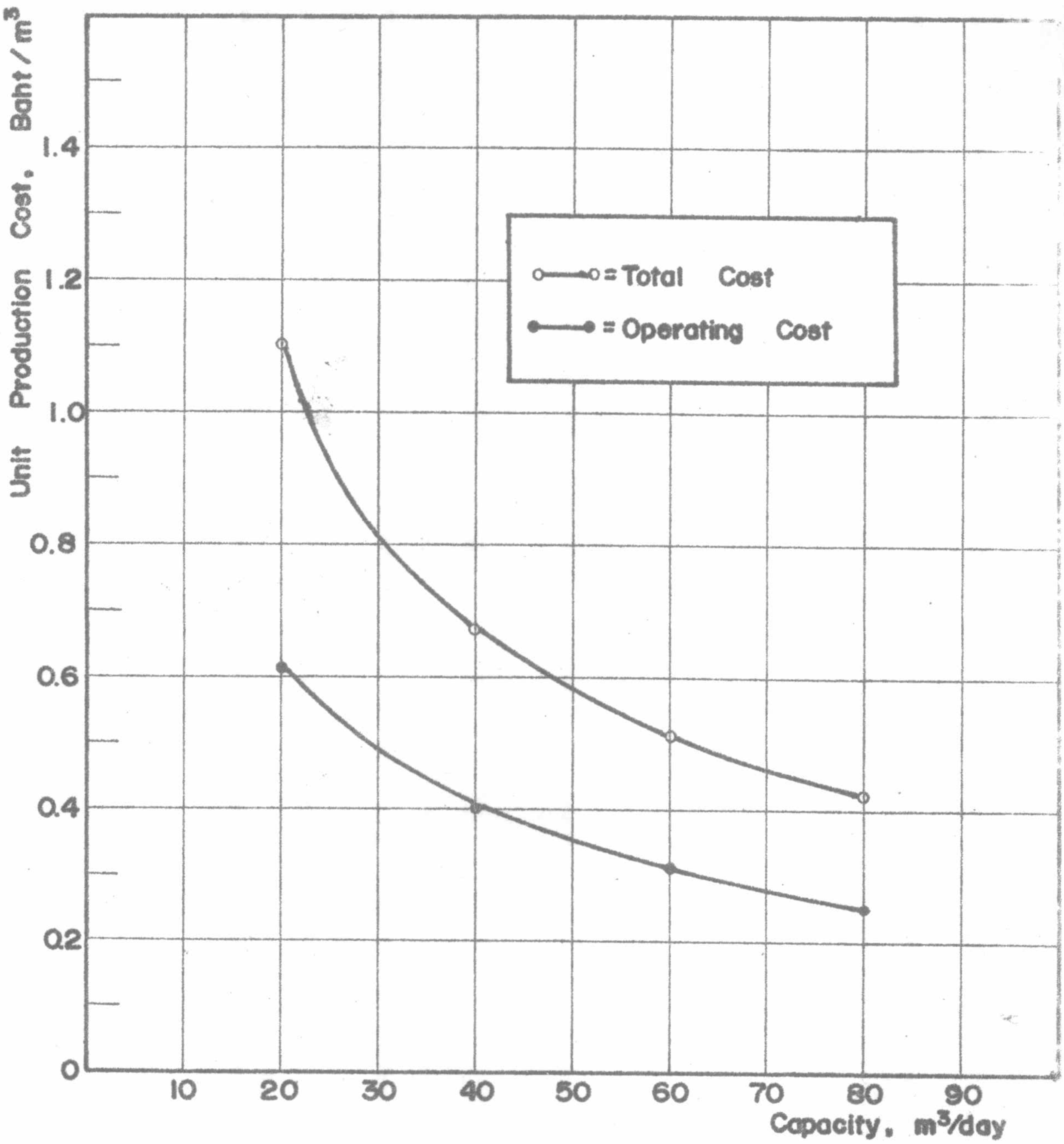


Fig.45 Total and Operating Unit Production Cost of Reclamation System at Various Capacities.

Table 25 Total Unit Production Cost of Various System at each Condition.

Type of System	Capacities, m^3/day / Conditions	Total Unit Production Cost, B/m^3 20	40	60	80
R	Service life of Concrete tanks 30 years, of piping system, pipe and underdrain and pump 10 years; operation 100% ; annual maintenance cost 1% of Capital Cost; interest rate 8%; and capacity of out put 100%	1.15	0.67	0.51	0.42
G_{100}	Service life of whole system 5 years; operation 100% ; annual maintenance cost 1% of Capital Cost; interest rate 8%; and capacity of out put 100%	2.79	1.51	1.08	0.86
G_{150}	Service life of whole system 5 years; operation 100%; annual maintenance cost 1% of Capital Cost; interest rate 8%; and capacity of out put 100%	3.15	1.68	1.19	0.95
G_{200}	Service life of whole system 5 years; operation 100%; annual maintenance cost 1% of Capital Cost; interest rate 8%; and capacity of out put 100%	4.24	2.23	1.56	1.22
W	Service life of whole system 10 years; operation 100%; annual maintenance cost 4% of Capital Cost; interest rate 8%; and capacity of out put 100%	2.60	2.59	2.58	2.58

Table 26 Total Unit Production Cost of Reclamation System Obtained from Changing each Variable of the Condition.

Changing Variable \ Capacities, m^3/day	New Value of Variable	Total Unit Production Cost, B/m^3 20	40	60	80
1. Service life of whole system	5 years	1.86	1.03	0.79	0.66
2. Percentage of operation	40%	2.46	1.33	0.98	0.80
3. Annual maintenance cost as percentage of capital cost	5%	1.35	0.77	0.59	0.49
4. Interest rate	12%	1.31	0.76	0.58	0.48
5. Percentage of out-put capacity	50%	2.02	1.11	0.83	0.67