into a final sedimentation tank, carrying with it such portion of the sludge as may be mixed with it.

Owing to the flocculent nature of this sludge most of it settles very rapidly to the bottom of this tank from which the clarified liquor passes to its ultimate point of disposal. That portion of the sludge which settles in the sedimentation tank is highly activated, and in order to keep the aerating tanks constantly supplied with the proper proportion of activated sludge, some of it must be returned to the raw sewage as it enters the aerating tanks, the balance must be removed at frequent intervals in order to maintain the proper sedimentation area in the tank and to prevent septic action which occurs if sludge of this character is subjected to anaerobic influences, as it would be in the bottom of a deep tank.

One of the primary features of this process is that it is susceptible of producing any standard of effluent required to meet the local conditions, and its first operating costs are almost directly proportional to the degree of purification demanded. The three principal items which affect the degree of purification and the cost are volume of air, period of aeration and volume of activated sludge required in the mixture. The greater the volume of air per gallon of sewage treated the greater the fuel cost. The longer the period of aeration and the greater the volume of activated sludge required in the aeration chamber, the greater the size of the tanks and their first cost.

One of the most comprehensive statements of the results obtained by variation in volume of air mixed with the sewage is that published by Mr. E. E. Sands, city engineer, in his report of his experiments conducted for the city of Houston, Texas, issued February 1, 1916, and from which the following table is extracted in brief:—

Table I.

Table Extracted from Page 44 of Mr. E. E. Sands' Report on Sewage Disposal for the City of Houston, Tex.

Item.	Crude sewage, parts per million.	Percentage of removal in 1 hr.	2 hrs.	3 hrs.	4 hrs.
Total organic nitrogen	5.5	64	65	66	67
Free ammonia	6.32	60	82	90	95
Dissolved oxygen consumed	103	97	98	98	98
Suspended matters	253	98	98	98	98
Nitrites and nitrates	Trace	4	8	10	11
Bacteria at 20° C. per c.c. ..	2,800,000	93.7	95.8	95.8	95.8

These results are averages from a large number of samples. The aerating tanks contained from 20 per cent. to 30 per cent. of activated sludge, and the mixture of sewage and sludge was treated with 0.437 cubic feet of free air per hour per gallon of sewage.

Diagnosing this statement it can be plainly distinguished that in Mr. Sands' experiments the clarification and bug removal were effected in the first hour with less than one-half cubic foot of free air per gallon of sewage treated; but it required four hours to reduce the free ammonia to nitrates. In other words, if a clear effluent with few bugs fit the local conditions one hour's aeration is all that is required, whereas if a stable effluent is demanded, four hours' aeration must be given.

From this statement it must not be concluded that in order to secure the results shown in Mr. Sands' statement for the first hour all that is necessary is to furnish 0.437 cubic feet of free air and aerate the sewage one hour, because this small volume of air and short period of aeration would soon impoverish the activated sludge which requires much more air than the raw sewage if the process is to be uniformly maintained.

While Mr. Sands makes no statement of this fact in his report, he has made provision for this in the large plant which he has recently designed for treating the sewage of the city of Houston by the activated sludge process wherein he provides for an average aeration period of one hour and fifty minutes for the sewage and four hours and thirty minutes for the sludge.

The investigations in Milwaukee upon the changes occurring in the sewage during the process gave somewhat similar results to those secured at Houston, although they were not as rapid.

The following table shows the average results obtained:—

Table II.

Statement of Certain Characteristics of Activated Sludge Process as Observed at Milwaukee, Wis.

Item.	Crude sewage, parts per million.	Characteristic changes in 1 hr.	2 hrs.	3 hrs.	4 hrs.	5 hrs.
Free ammonia ..	20.3	14.9	13.2	11.1	9.3	7.4
Nitrites	0.12	0.25	0.84	1.25	1.37	1.56
Nitrates	0.09	0.69	1.24	3.28	5.71	7.90
Dissolved oxygen	0.03	0.51	2.30	4.14	5.56	5.70
Stability in hours	0.0	9.4	45	120	120+	120+
Bacteria at 20° C. per c.c.	466,000	71,800	27,000	11,800	6,800	2,900

The aerating tanks contained from 20% to 30% of activated sludge. The sewage was treated with 0.375 cu. feet of free air per hour per gallon of sewage.

Attention is particularly called to two or three things appearing in Table II., *viz.*:—

The progressive steps required to convert the free ammonia into nitrites and finally into nitrates. How little is accomplished the first and second hours, and how much during the third, fourth and fifth hours. Following this characteristic is the rapid increase in dissolved oxygen and the stability of the liquor, indicating pretty clearly that if a stable effluent is required good nitrification must be established.

The greatest effect upon bacterial removal occurs during the first hour. This is doubtless due to two things: the rapid digestion powers of the organisms in the activated sludge, and the flocculent character of the sludge to which these bacteria naturally adhere, just as they do in the floc produced by chemical precipitation.

The amount of activated sludge mixed with the raw sewage as it is being aerated affects the degree of purification to an important extent. To obtain an equal standard of effluent, if the sludge volume is reduced the volume of air must be correspondingly increased and the period of aeration. The Milwaukee experiments indicate that a clear and stable effluent can be obtained from the Milwaukee sewage by mixing from 20 to 25 per cent. of activated sludge for four hours with about 1.75 cubic feet of free air per gallon of sewage treated.

As the sludge is precipitated to the bottom of the sedimentation tank it contains approximately 98 to 99 per cent. water; therefore, to get a mixture of 25 per cent. of sludge back into the aerating chamber a volume equal to about 40 per cent. of the raw sewage must be returned; that is, the mixture of sewage and sludge passing through the aerating chamber will approximate 140 per cent. of the raw sewage being treated. This fact must not be lost sight of in determining the size of the aerating chambers in allowing for a certain period of detention.

In order to determine the percentage of sludge in the aerating chamber the Milwaukee practice has been to fill a calibrated tube with the mixture, and at the end of one-half hour determine by volume the percentage of sludge settled.

One of the important features of this process is the proper design of the sedimentation tanks. The sludge is