Design of Contact Filters To Serve 10,000 People

by Carl Pleasant

1911

Submitted to the University of Kansas in partial fulfillment of the requirements for the Degree of Master of Science

1245 Rhode Island Street,

Lawrence, Kansas,

June 5, 1910.

ofessor W. C. Hood,

Associate Professor, Civil Engineering,

University of Kansas,

Lawrence, Kansas.

ar Sir:

I hand you herewith for your approval my thesis, which is design of a series of Contact filters to serve ten thousand people.

Very respectfully yours,

Carl Pleasant

THE DESIGN OF A SERIES OF CONTACT FILTERS

TO SERVE TEN THOUSAND PEOPLE.

THESIS

PRESENTED FOR THE DEGREE OF

MASTER OF SCIENCE

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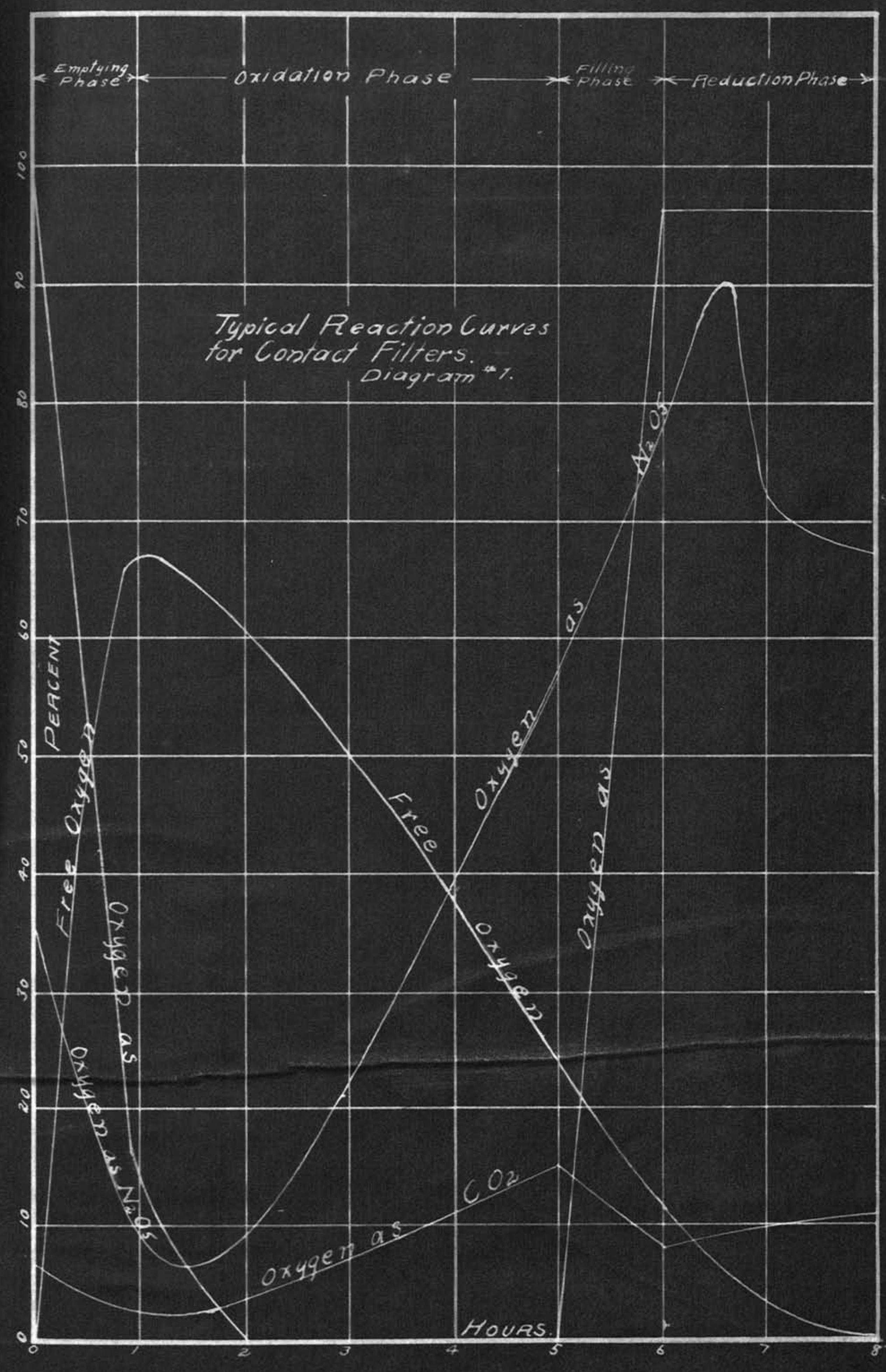
Typical Reaction Curves
for Contact Filters.
Diagram #1.
Emptying Phase
Oxidation Phase
Filling Phase
Reduction Phase
PERCENT
HOURS.
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
Free Oxygen
Oxygen as
Oxygen as N_2O_5
Oxygen as CO_2
Free Oxygen
Oxygen as N_2O_5
Oxygen as

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DESIGN OF CONTACT FILTERS TO SERVE 10,000 PEOPLE.

1.

The object of this thesis is to design a series of contact filters to treat the sewage from a population of ten thousand people. The sewage is assumed to be ordinary house sewage, unaffected by a considerable volume of trade waste. The quantity of the sewage is estimated on an assumed average rate of water consumption of one hundred gallons per capita per day, the sewage flow per day being taken as equal to the water consumption. The population of ten thousand is taken as being typical of a large number of Kansas towns for which this design is intended to be applicable, and the assumed water consumption and sewage flow above mentioned have been shown by investigators to be good average value, and not too small. Preliminary treatment in a septic tank is also assumed.

It has not been the aim of this thesis to design a series of filters that will be quite different from anything yet built, but rather to investigate all designs made to date, with the view of determining the desiable features of each, and incorporating them so far as possible into the plant under consideration. With this idea in mind the writer has endeavored to review recent literature on the subject, giving special attention to the technical journals of the last five years. English and American methods of design have both been studied, the English in the writers opinion excelling in the careful compilation of data, while the Americans excell in the constructive design.

GENERAL DISCUSSION OF PROCESSES.

II.

A contact filter may be roughly described as a bed of porous material on to which the sewage is fed and allowed to stand for a short while in the presence of oxygen or air, in contact with a gelatinous mass of bacteria. For the porous material broken stone, cinders, broken glass, or other irregular material may be used. In diagram is shown a typical reaction curve for the filter. It is of course an average of a large number of filters and may, therefore, be said to be " typical." According to the usual method of construction the sewage is led in from the top and trickles down from over the entire surface and through the porous material to the bottom or to the gradually rising water level. At the top it comes at once in contact with a heavy gelatinous film, a bacterial growth. This zooglia consists of bacterial capsules, each bacterium being covered with this gelatinous growth. The organic matter is here dissolved by the capsule and the finely divided solid matter is filtered out and retained by the sticky mass.

Now drain out the beds slowly, the sewage sinks and the air follows it down, and is brought into direct and immediate contact with the dissölved organic matter and with the fine solid matter clinging to the above mentioned filtering material. This especially favorable to oxidation, and the disolved and solid matter, in the presence of the bacteria and a good concentration of oxygen undergoes rapid oxidation. Upon this zooglical film together with the presence of available oxygen the action of the filter is dependent. The greater the surface, then, the more of the bacterial growth available, and the greater should be the efficiency of the filter, and ~~from~~ this leads to the conclusion that the smaller the stones - if broken stones be used - the greater the efficiency of the filter, since the smaller sizes of stone give greater surface area. However, we must not forget that the oxygen plays an important part and a vital one in the process, and if the stones are too small then the voids are likewise narrow and the air passages necessarily insufficient. The filter then sludges up and an actual decrease in efficiency results.

When the filter beds are filled a reaction occurs that is the exact oppisite of that which occurs during the so called " oxidation phase," or period when the beds are empty. As will be seen from the diagram, during the oxidation phase there is a marked increase in nitrates but in the reduction phase these nitrates decrease, while the nitrites increase. This means that the nitrates are to a certain extent used up in some manner and are transformed back into nitrites. The incoming sewage contains many compounds in a low state of oxidation themselves and in the establishment of equilibrium the nitrates are reduced back to nitrites and the oxygen they give up is used in the oxidation of the lower compounds.

It is the putrefaction of the nitrogenous compounds in the sewage that give off foul odors and create nuisances. It is therefore essential that the effluent shall contain no putrefactive matter, and that oxidation shall be complete.

It has been noticed that the total nitrogen content of the sewage entering the filter is in excess of that coming out. A decrease of as much as thirty, forty, and even fifty percent has been noticed. This has been found to be due to the reductions above noted during the reduction or filling phase, in which the reduction does not stop with the formation of nitrites for the nitrogen is reduced even to the full uncombined state.

As a resume we may say that the organic matter is taken out by absorption and filtration, and stored in the filter. In the oxidation phase after emptying it is oxidized. During the next filling the oxidation products are reduced to a certain point in the oxidation of the incoming sewage.

RATE OF FILLING.

1. Since the entire action of the filter is an oxidizing one, it is highly desirable to entrap all the air possible within the beds. This action is greatly increased by rapid filling. If the beds are filled slowly the sewage trickles down to the bottom and forces the air up while if they are filled rapidly the air is entraped in the voids of the stone and retained. Most English writers give one hour as the maximum time of filling, but American engineers prefer a much shorter time, one - half hour being a common maximum figure given. The writer thinks it advisable to cut this time as low as is possible and would favor beds of such size as could be filled well within the limit stated. To this end dosing tanks in which a considerable quantity can collect and be flushed out rapidly on the beds desirable and in most cases quite necessary to efficiency.

TIME OF EMPTYING.

2. The time of filling and emptying with the time of standing empty or resting determines the number of doses per day, and therefore the capacity of the plant. This is one reason for rapid rates of emptying. But in accordance with the general behavior noted in diagram 1, a de-

nitrification takes place on emptying, during the reduction phase. The more quickly the emptying is done therefore the less this loss. Also rapid emptying produces better aeration, draws the air down after the receding sewage, and brings it in contact with all the filtering material. It also tends to prevent sludging up. If a bed drains very slowly any oxidizable sediment which has settled out will remain in the filter, while it would very largely at least, be carried out by a faster flow.

TIME OF STANDING FULL.

3. English writers generally prefer a longer time of standing full than Americans but this is probably due to the stronger sewage they have and also to the lack in many cases of preliminary treatment. The English recommendations vary between one and two hours, while Americans have found the shorter periods more advantageous. If the sewage is allowed to stand too long reduction is found to increase very largely.

NUMBER OF UNITS.

4. For efficiency four units may be considered a minimum. The number of units depend upon the period of rest, as the time of filling and emptying is made as short as possible for other reasons. It has seldom if ever been found satisfactory to fill more than three times per day. In other than small plants where beds are of

such dimensions as to admitt of rapid filling and emptying six units will generally be found desirable.

FILTERING MATERIAL.

5. Slate, limestone, brick, slag, clinkers and broken glass retort necks and the like have all been used. Cinders disintergrate, and are apt to contain too much fine material, and when they are specified it should be required that they contain no pieces of less diameter than three fourths to one inch. Broken glass has proven excellent but has not been generally available.

Mr. W. J. Dibdin gives an interesting table comparing several filtering materials, based on percentage **of** Albuminoid Ammonia removed.

	Parts per 100,000	Percent Purification	Lowering of Septic Tank.	Difference after three months.
Sewage	100			
Septic Tank	81			
Slate	51	36	6 1/2	3/16
Limestone	54	34	4 1/4	1/16
Brick	51	38	4 1/2	0 0
Slag	56	32	4 1/8	9/16
Clinkers	48	41	4 5/8	1/16

In the above limestone is seen to make a favorable showing, and together with its availability and cheapness makes a desirable material. It is advisable to keep the upper layers of the filtering material perfectly clean as sediment and grass and weeds if allowed to collect will prevent proper aeretion.

DEPTH OF BEDS.

6. Beds can be properly aerated only to small distances below the surface and this contingency practically limits the allowable depth. From 3 1/2 to 4 feet has generally been used in this country and has been found to give the best satisfaction. Greater depths give less efficiency, smaller depths will increase the cost.

The preceding pages discuss different functions of the filter and the following pages will give an explanation of the design adopted by the writer, and his reasons therefore.

DISCUSSION OF THE PARTICULAR DESIGN.

III.

Three elements have grounded the preparation of the design submitted. Accessibility to all parts of the plant is desirable, low cost must always be kept in mind, efficiency is absolutely necessary. A high degree of efficiency in the plant, with the integral parts thereof collected under one roof and readily accessible, all provided at minimum cost of construction is the aim of the accompanying design.

Sheet No. 1 of the plams accompanying this manuscript shows general plans of the filters and the arrangement of the several parts. The general plan of the system will be seen to be hexagonal in form. To the knowledge of the writer no plant of this type has as yet been built. The writer is indebted to Prof. W. C. Hoad of the University of Kansas for this idea.

This shape is found to give more economical construction than the usual type with rectangular over all dimensions, and trapezoidal individual filter beds. It needs no discussion to show that the excavation for a hexagonal filter is less than for rectangular filter of the same capacity, and also that the concrete quantities for the dosing chamber are less than with rectangular shape. As to the filter beds themselbes, it is not possible to draw general mathøtical conclusions with regard to shapes, but comparative estimates showed less concrete was required with the hexagonal design for this particular plant, than with the custömary rectangular and trapazodial units.

In this arrangement each bed is alike, has the same form throughout, and the same dimensions over all and through all sections, and this should materially cheapen the cost of construction. The dosing chamber is of course higher than the filter beds and the space below them is utilized for the collection of the outlet pipes that drain the beds. A large central manhole is placed in the dosing chamber and all the subdrains empty into this and are carried away by a single pipe.

The entire design is made so far as possible monolithic. All the machinery is collected under one roof as are the alternating dosing siphons and the timed siphons. A five foot reinforced concrete walk extends around the entire interior of the building and around the central manhole, so that every part of all the dosing and emptying apparatus is immediately accessible under one roof.

The sewage from the septic tank is brought into the dosing chamber through an inverted siphon. This puts the siphon out of the way and also secures it from injury. The pipe is chosen of such size and laid on such grade that the sewage will flow through it with a minimum velocity of 1.5 ft. per second when running at average flow. The maximum rate of flow is taken as three times the average rate for the day, or three million gallons. A fourteen inch pipe is found to carry one million gallons per day when flowing at the rate of 1.5 ft. per second, the loss of head being 0.7 ft. per thousand feet. When carrying at the rate of three million gallons per day the velocity is 4.3 ft. per second and the loss of head is 6.0 ft. per thousand feet or 1.2 ft. loss of head in 200 ft. from the septic tank to the filters.

A 12 inch pipe gives a two feet per second velocity at the rate of one million gallons per day, but requires a loss of head of nearly 2.5 ft. at the maximum rate. The 14 inch pipe is therefore chosen and due allowance in grade is made to offset the loss in head during maximum flow. As before stated it is desired to dose the contents of the dosing chamber upon the beds as quickly as possible in order to entrap the air within the beds as much as possible. With this end in view 21 inches fall is given between the bell of the dosing siphons and the surface of the sewage in the filters at its highest point. It is quite possible that in some cases not so much fall as this would be available, but the effect of quick dosing is such that the fall given in this case is extremely desirable.

Twelve inch alternating dosing siphons are used which the makers guarantee to empty the tanks in twenty-five minutes. Too slow rate has the same effect as too long a time of contact in the causation ofthe reducing action. The siphons discharge into 15 inch mains in order to secure unhampered flow. These distributing mains lead down the center of the beds and discharge through their own open joints, vitrified clay sewer pipe being used - and through 6 inch tees spaced five feet apart. This allows alternate junctions - one to each 2 1/2 ft. joint of pipe. From the inner end of the beds to the outer there is a fall of four inches to insure proper dosing at the outer end. Thirty feet out the mains decrease to 12 inch pipe and then at thirty-four feet farther they decrease again to ten inch pipe.

Owing to the sludging up of the beds which invariably occurs after they have been in use for some time, the capacity is decreased and the usual result is that the sewage rises higher than at first intended. Sometimes it rises even above the stone and to the top of the pipes. To guard against this the siphons to be used in this filter system do not vent themselves. When the beds are full (see sheet four) a venting chamber is filled by means of an auxiliary siphon and in this, air is compressed in a drum and breaks the water seal and stops the flow. In other words the sewage will flow till the bed is full and then it willstop. On the other hand should the dosing chamber not supply sufficient sewage to fill the beds to the desired level, the siphons will not vent themselves but will continue to run until the bed is full and is vented by the means of the venting chamber and auxiliary siphon above described.

The filtering material used is broken limestone of good quality that will pass a two inch mesh and will be retained on a one inch mesh. It is chosen on account of its durability, its cheapness and also its efficiency. In calculating the size of beds the percentage of voids was taken at 33 1/3 %. Any small error in this factor, either at the time the beds are made or caused by subsequent sludging up is amply provided for in the dosing apparatus described above.

The depthsof the beds was made an average of 3 feet and 6 inches. In the deepest place they are three feet and nine inches and in the shallowest place they are three feet and three inches, giving an average depth of three feet and six inches.

The subdrains are of common drain tile laid with loose joints. (See sheet five) At the outer end a ten inch pipe is laid with six inch laterals leading from it. The main is laid in a groove in the floor so that the bottom of the tees leading from it are flush with the floor. The floor itself has a fall of six inches from the sides to the centre. In the floor grooves are made for the drain tiles to lie in in order to keep them from getting pushed out of place. The mains themselves are then given a slope in an inclined ditch cut along the centre of the beds. This slope amounts to 12 inches from the far end of the beds to the time siphons. This fall may not always be available in specific designs, but should be given if possible .

In desigining a system of this kind to be used with out a previous survey of the ground where it is to be built, one must expect the probability of some changes in plans. Thus it may be that the fall to the outlet at a given location is such that the loss of head both at the alternating siphons and at the timed siphons will have to be reduced, but the grades here given are chosen as in all cases desirable and also reasonably to be expected. A further 6 inch drop is necessitated at the timed siphons but no additional drop is required to reach the outfall manhole. At the outfall manhole a 6 inch drop is given to accelerate the delivery into the outfall main.

It will be noticed that the subdrain pipes are placed directly beneath the distribution pipes. Inasmuch as there is never any current through the subdrains while the sewage is flowing through the distribution pipes there is no reason for avoiding this feature.

The inside wallsof the timed siphon chambers are carried up to the level of the main floor over the dosing chamber. Iron steps then make the siphons readily accessible. The small pipes used in the timing devices are then fully protected from frost under all conditions. The dosing and emptying apparatus, in fact all the mechanism of the entire plant is assembled within the one building. Walks extend around the entire perimeter of the building, and connect the central platform and dosing chamber with every piece of apparatus used. The labor of supervision and inspection is thus reduced to a minimum, and the expectancy that each unit will work at its full capacity is correspondingly.increased. Ten inch siphons guaranteed by the makers to empty the beds in 25 minutes are used.

The walks are designed to carry a load of 200 pounds per square foot. Stresses are calculated by the straight line formula and the dimensions and reinforcement are taken from Schermerhorn's tables. Six hundred pounds compression per square inch is allowed on the concrete, and 16,000 pounds per square inch is allowed on the steel. Twisted steel bars having a guaranteed elastic limit of 35,000 pounds per square inch are used throughout. Twisted bars are used on account of the difficulty of anchoring firmly a rod of the short length used in this construction.

The machinery house is reached by a reinforced concrete walk between beds 1 and 2, and leads directly to the door of the house. The beams used are supported by columns where they cannot rest upon a wall. Columns are 6 inches square and rest upon base blocks 2 feet square. Base blocks are 1 foot thick under the dosing tank on account of made ground and but six inches thick under the filter beds.

The machinery house walls are made of No.2 dry pressed brick, laid as stretchers with blind headers spaced two feet apart every fifth course. Light for working in the pits is amply provided by placing two double 26" x 30" windows in each of the six sides of the hexagone. A 2' - 8"" x 6' - 8" door opens on the outside walk. 2" x 8 " rafters run up from the six corners, with 2" x 6" Jack rafters, 1" x 6" sheeting carries a tile roof over all.