EXTENDED AERATION

A POSSIBLE TREATMENT FOR POULTRY PROCESSING WASTES

RAJA F. HALAZUN

Advisors:
Prof. S. K. Khouri
Prof. A. N. Acra

THESIS PRESENTED IN ~~PARTIAL~~ FULFILLMENT
OF THE
DEGREE OF MASTER'S OF ENGINEERING

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THESIS

M. Eng.

RAJA F. HALAZUN

AMERICAN UNIVERSITY OF BEIRUT

Addendum to Thesis presented to

School of Engineering

As a result of the questions and discussions during the oral defense the following modifications should be made to the text.

Title: Extended Aeration a possible treatment for poultry processing wastes.

Preface: A new opening paragraph should be added:
"This Thesis presents a scientific exploration of the use of the extended aeration principle for the treatment of poultry processing wastes as exemplified in the Shuman poultry plant in Beit-Miri.

The Shuman plant in Beit-Miri, after its proposed expansion, is considered a typical example, and the results of this study are expected to be of use to other poultry processing plants under the same conditions and limitations with the following reservations: 1. That the volume of waste water flow is substantial. 2. That all simpler treatment processes are eliminated (ex: septic tanks and seepage pits)."

Introduction: **A.** Add at the end of para. 2:
"... which is taken as an example of poultry processing industries employing modern techniques".

C. After Para. 1, add a new paragraph:
"It is intended to study the possibility of the use of extended aeration for the treatment of poultry processing wastes.

...

A comparative evaluation of this treatment is given to support the appraisal of the extended aeration unit. In addition, a theoratical research is presented to give enough~~t~~ background for the proposal.

A selection of the particular extended aeration unit is made on basis of simplicity of operation and maintenance, efficiency, practicability, originality and cost. Data about extended aeration is used critically and a scientific synthesis of available information on design is used for the verification of the manufacturers' unit.

A basic assumption is used in this project that there is no sewarage system close to the Beit-Miri plant to which it can connect, that might deflect the basic findings of this Thesis".

D. Add at the end of para.3:

"Poultry wastes are in fact hazardous in the same sense as domestic sewage. The processes do not produce any toxic or mineral wastes of a special nature, and hence the singularity of the waste is in its concentration rather than its organic nature."

CHAPTER II: Add at the end of Section (ii) p. 41.

Grease produced is in the order of 3.9 lbs per day and this might affect the proper flow of liquid wastes in the irrigation pipes, but is not expected to be a main nuissance.

CHAPTER III: Add at the end of para. 1. p. 50.

The Dorr-Mineralisator is a development of the Pasveer ditches which could have been a possible alternative treatment.

Summary:

The summary should have been placed at the beginning of the text.

Errata:

Some typing mistakes are corrected in the presented texts.

R. F. H.

19 October 1965

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PREFACE

This thesis is intended to present mainly a selection, evaluation and design of a treatment plant for the waste waters from the Shuman's poultry processing plant - Beit Miri, after it has been expanded to produce 3000 chickens per day.

Poultry processing offers a singular industrial waste, and hence a study of the required treatment has to be done in light of the processing operations and the nature of waste produced; in addition to an understanding of current practices in the treatment of poultry wastes.

Current methods of treatment of similar cases are studied in the light of their flow capacities, characteristics of wastes, efficiencies of treatment, and initial and operating costs.

Selection and evaluation of the method used and a research on most acceptable treatment methods for similar wastes are presented.

A scientific verification of the manufacturer's design of the proposed extended aeration unit is also presented.

This study is expected to be useful for finding treatment methods to be employed for similar poultry processing plants or any other industrial process that produces highly organic wastes of the same nature. It will be found useful for the treatment of sewage from small communities since the treatment method that is selected employes the extended aeration principle which has found a successful application there.

Extended aeration is a recent development of the "conventional" activated sludge method and operating data is not amply available in sewage text books. Most of the literature is found in the form of articles in journals or pamphlets. Many contacts for literature were made. The Robert A.Taft Sanitary Engineering Centre, the ASCE-Sanitary Division, water and sewage journals, manufacturers of sanitary equipment, water and sewage engineers offered valuable pertinent literature.

In conclusion, I would like to express my acknowledgement and gratitude to the professors of Sanitary Engineering: to Prof. E.S. Hope, Prof. S.El-Khouri and Prof. A.N. Acra for their helpful advisorship and their keen interest; to ACE for allowing me the use of their library; to Mr. H. Shuman for his help and kindness, and to all who helped by offering pamphlets, papers and advice.

September, 1965. R.F.H.

INTRODUCTION

A. GENERAL

Perhaps the most challenging field in sanitary engineering practice at the present time is the treatment and disposal of industrial wastes. The importance of industrial wastes can be more appreciated if one realizes that the population equivalent of industrial wastes in the United States can reach as high as the number of its inhabitants[1].

The poultry processing industry produces an industrial waste that requires study from the sanitary engineering point of view. This report deals with the study of the liquid wastes of Shuman's Poultry Processing Plant in Beit Miri, Lebanon.

A proposed method of treatment and disposal of the liquid wastes produced is presented together with the reasons for selection of the proposed plant and its design. Current methods of treatment of similar wastes, a thoratical evaluation of the proposed treatment and its cost analysis are also presented.

B. POULTRY INDUSTRY IN LEBANON

Poultry processing industry in Lebanon has been developed only recently. Before 1952 there was no poultry production on an industrial scale in Lebanon at all[2]. There was only one semi-commercial poultry farm in 1952. All farmers interested in poultry processing were primarily afraid of chicken diseases[2]. Techniques of feeding, breeding and processing poultry were not yet modern and perhaps primitive.

As the demand for processed poultry was higher than the Lebaneese market could supply, interested farmers started thinking of modern poultry processing plants.[2] In 1954 Hassan Shuman constructed his first farm in Beka'a under the influence and guidance of the United States Operation Mission to Lebanon. He erected modern buildings, used up-to-date equipment, purchased top quality broiler chicks and applied modern methods of production and management practices. Twentysix poultry farms followed the steps of Shuman's trial in Beka'a each producing 500 broilers per week. Fourtytwo new poultry houses were constructed during 1958-1959 and the production during that year was in the range of 300-2000 birds per week each[2]. In 1963 Shuman started another farm in Beit Miri. The average number of processed poultry in 1963 from the new plant in Beit Miri was 3600 broilers per week while the average number of processed poultry from the Beka'a plant in 1963 was 2400 broilers per week.

Shuman expects to expand the farm in Beit Miri still further to take the increasing demand. He plans to acquire new equipment used in modern poultry farms in the United States. It is expected that such a plan might be put into effect in two years.

The expected production of the expanded plan in Beit Miri is 18000 processed chicken per week.

C. NATURE AND SCOPE

On the basis of the fact that the poultry industry has expanded so greatly in Lebanon in the last ten years, and with an understanding that such an expansion might mean an increase in the amount of waste from such an industry, this report presents a study of a treatment method for Shuman's farm of Beit Miri, since it is one of the typical farms in Lebanon, and since it is bound to present problematic situations as far as treatment is concerned.

Modern techniques in poultry processing will be adopted in the Beit Miri farm and the production of processed poultry is expected to increase in the Beit Miri farm from 600 birds per day to 3000 birds per day, by the introduction of a conveyor line-type-system.

In presenting the study for a treatment method for the wastes from Shuman's poultry processing plant in Beit Miri, it is essential that a description of the different processes should be given, as well as the nature, source, characteristic of the wastes produced[1,2].

The fact that Shuman intends to expand the Beit Miri plant is given careful consideration in the present study. The description of the change in the poultry processing plant resulting from such expansion is also discussed, because of its effect on the nature and characteristics of the poultry farm.

The practice in the United States in poultry processing is given special attention since Shuman intends to follow the American practice in poultry processing and mainly because of the great advances in poultry farming and processing in that country.

Production figures of processed poultry are important in waste treatment because they provide an estimate of the quantity of waste produced. In that respect, there is some analogy between production figures of processed poultry and population figures for the design of domestic treatment plants.

In this study consideration is mainly given to water consumption and hence the flow per unit of processed chicken, certain chemical and biological characteristics of the wastes, hours of production per day, topographic and agricultural nature of the soil, economic and operational problems connected with the waste treatment and pollution of underground water.

The cost analysis of the proposed treatment plant is also considered because it determines the economic feasibility of the project.

D. PURPOSE

The study of a treatment method for Shuman's poultry processing farm in Beit Miri can be useful for poultry processing farms with such a problem.

The various poultry processing farms in Lebanon are scatered throughout the country. Many of these farms are producing an estimated average of 300-400 birds per day.[2] Disposal of poultry processing wastes in these farms is generally done by the use of septic tanks, and as a typical example the Shuman poultry processing farm at present has a septic tank and an infiltration pit for the treatment of its liquid wastes, while solid wastes are incinirated and burried.[2]

The hazards arising due to the improper disposal of poultry processing wastes are mainly a result of:[3,4,5] (a) Possibility of presence of pathogenic bacteria, (b) Odors especially the formation of H 2 S gas when the wastes become septic, (c) Flies and insects, (d)

Pollution of ground water.

Thus it is seen that this study of a treatment method for Shuman's poultry processing plant in Beit Miri, in addition to solving the problem there, should serve as a pilot project for other plants operating under similar conditions.

CHAPTER ONE

SHUMAN POULTRY PROCESSING FARM IN BEIT MIRI

A. DESCRIPTION OF THE FARM

1. Location

Hassan Shuman's poultry processing farm is located in the suburbs of Beit Miri, one kilometer down the hill from Beit Miri Qalaa, at the extreme south of the town. It is connected to Beit Miri by an access road, about 300 m. in length, which is partly paved. A plan of the farm is shown in Appendix I.

2. The Land

Only a part of the farm is used for agricultural purposes; and the other part is heavily forested.

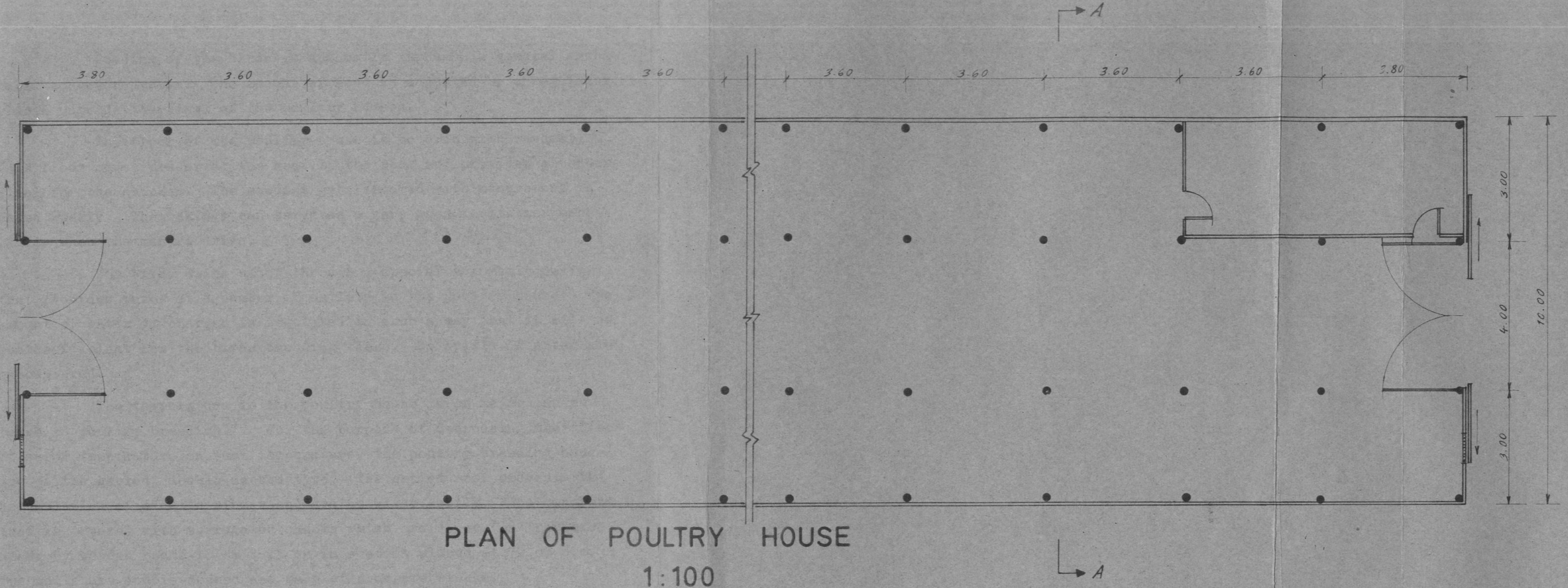
The plot on which all the existing farm is constructed is almost triangular in shape, with deep sloping contours. The land slopes rather steadily in the North Western-South Eastern direction from a relative height of 687 m. to a relative height of 645 m. with a difference of 42 m. from N.W. corner to the S.W. corner. A contoured map of the farm is shown in Appendix II.

3. The Units of the Farm

The Shuman poultry processing plant in Beit Miri consists of the following units: (i) Poultry breeding houses, (ii) Offices and guard's house and (iii) Poultry processing slaughter house.

(i) Poultry breeding houses: The poultry breeding houses are put into four wings of two compounds. Each compound is made of two identical wings. Plans and sections of the poultry houses are shown in Figures I.1 and I.2. Each of the four wings usually holds over 6000 birds.

Shuman has already made plans for a fifth wing to be used as an additional poultry breeding house. It is 40 m x 10 m, to be built parallel to the northern wing of the higher compound. It is anticipated that the new wing will hold over 6000 more birds.



PLAN OF POULTRY HOUSE
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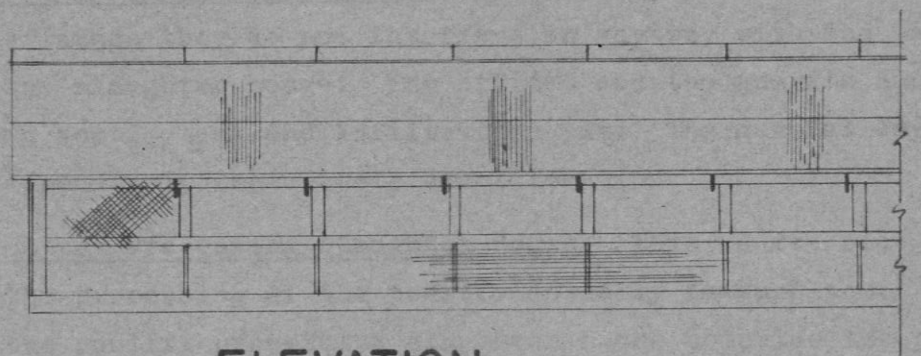

ELEVATION
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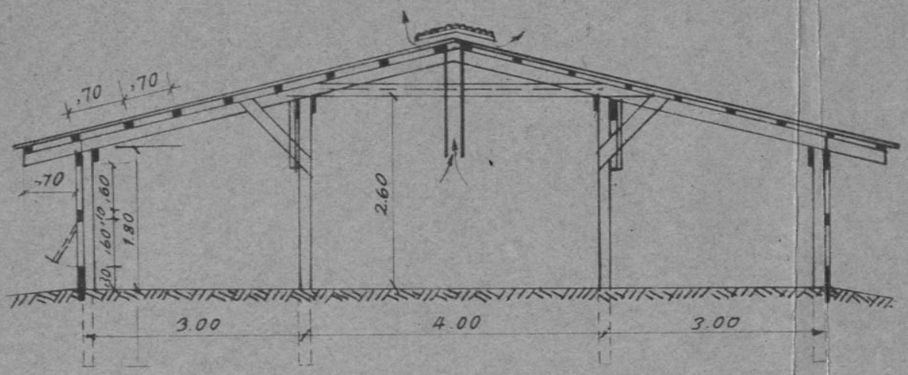

SECTION A-A
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Diagram I. 1.

Feeding of the birds is automatic through a special mechanical conveyor system. The amount of food is adjusted by a regulator placed outside the wings of the poultry houses.

The floor of the poultry house is covered with sawdust. This floor cover preserves the heat in the room and provides a tender floor for the chicken. The sawdust gets smeared with manure and is raked weekly. The rakings can serve as a very good fertilizer especially when the manure dries.

The birds drink water through a special automatic device that provides water at a number of outlets in the poultry house. The amount of water discharged is regulated in such a way that it will be just sufficient for the birds breeding there. No spills of water are encountered.

The temperature in the poultry house is of major importance to poultry breeding.[2,3] For the purpose of decreasing the effect of outer temperature on room temperature, the poultry breeding houses are of the gabled, double decked type. The gabled roof prevents the accumulation of snow in winter and drains water easily. The concrete roof is covered with corrugated sheets which are seperated from each other by wooden beams 10 cm x 15 cm in section placed at 70 cm c.c. The walls are double-decked and made of concrete blocks.

(ii) <u>Offices and Guard's House</u>: These are of no significance to this report since they do not interfere in any way with the waste waters from the slaughter house. The offices and the guard's house have their own septic tank and infiltration pit. The general layout, attached as Appendix I, shows their exact location.

(iii) <u>Poultry Processing Slaughter House</u>: This is the slaughter house where the processing of the poultry actually takes place. The wastes from the poultry processing slaughter house comprise the problem under discussion.

The processing slaughter house is 25.0 m x 10 m. All the processes take place in the slaughter house. No partitions are built to separate the processes from one another, with the only exception of the refrigiration and packing room. All the walls are glazed tiled for better cleanliness. A plan of the slaughter house is shown in Figure I.3.

B. THE POULTRY PROCESSES

The poultry processes will be discussed in two separate sections: (1) Practice at present in Shuman's processing plant in Beit Miri. (2) Future development of poultry processing. The expanded plant is to be done by installing an automatic type system that can produce 3000 birds per day as anticipated.

1. Practice in Shuman's Poultry Processing Plant

The poultry processing operations are grouped and discussed in the order shown in the line diagram of the poultry process. The line in Figure I.4 shows the appropriate location of each operation with respect to the slaughter house.

Following is a description of each of the processes outlined in the Figure I.4 showing the main contributions of waste to the sewer.

(i) Receiving. The first stage of poultry processing in this slaughter house is the receiving of live birds. The live birds are unloaded in coops from wagons bringing them from the poultry houses described above. This is a daily operation in this farm. The number of poultry brought in is usually exactly equal to the number of poultry to be processed.

(ii) Killing. Figure I.5 shows the arrangement of the killing operation schematically. Killing is done in one machine that has six inverted cones that can be rotated by hand, and in which the birds are fitted with their heads down. The rotation of the machine is to help the laboror kill the next bird without moving around. This is just for convenience. The killing operation is done by the severance of the jugular vein. The killing machine is provided with a small outlet to drain all the drainable blood into a trough. This is the measure taken for blood recovery. Blood recovery relieves the waste water from the processing slaughter house from some blood which is of a high pollutional effect (BOD = over 92,000 mg/l).[3] Recovered blood is inci-

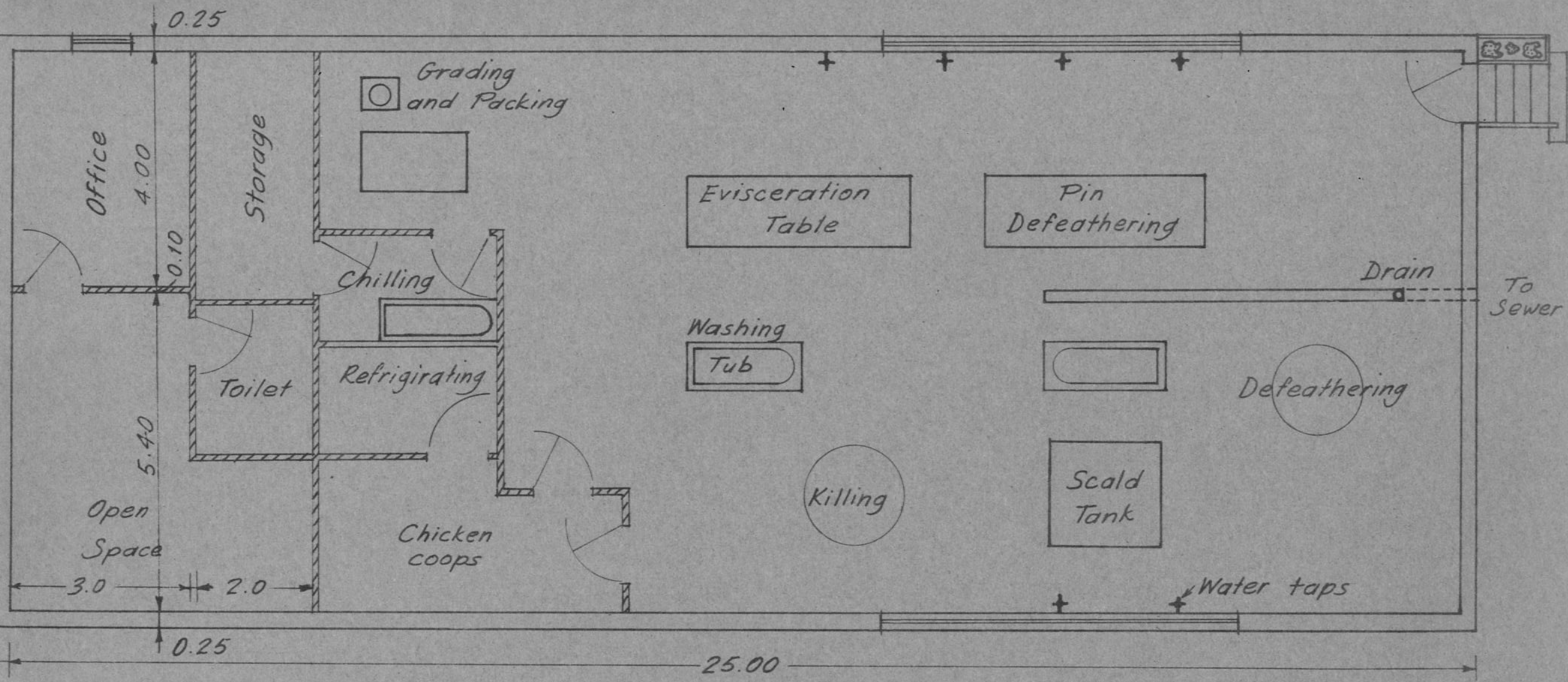
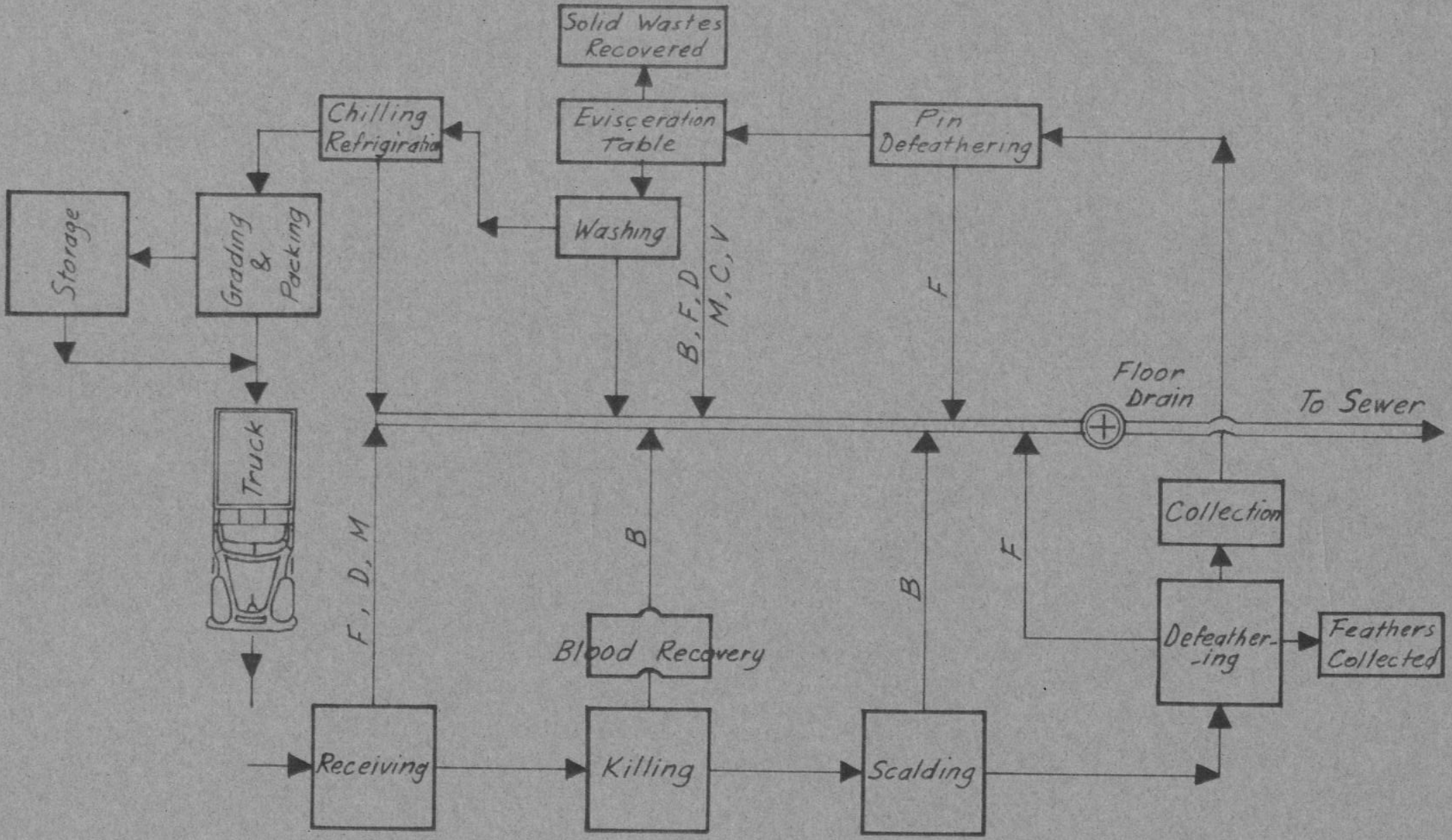


Diagram I.3.

PLAN OF SLAUGHTER HOUSE
1:100

Diagram I. 4



BLOCK LINE DIAGRAM OF PROCESSING PLANT SHOWING MAIN CONTRIBUTIONS OF WASTE TO SEWER

LEGEND:
Solid line = waste water line, lines reaching solid line are waste water from different processes
B = Bloods, C = Cuttings, D = Dirt, F = Feathers, M = Manure, V = Viscera

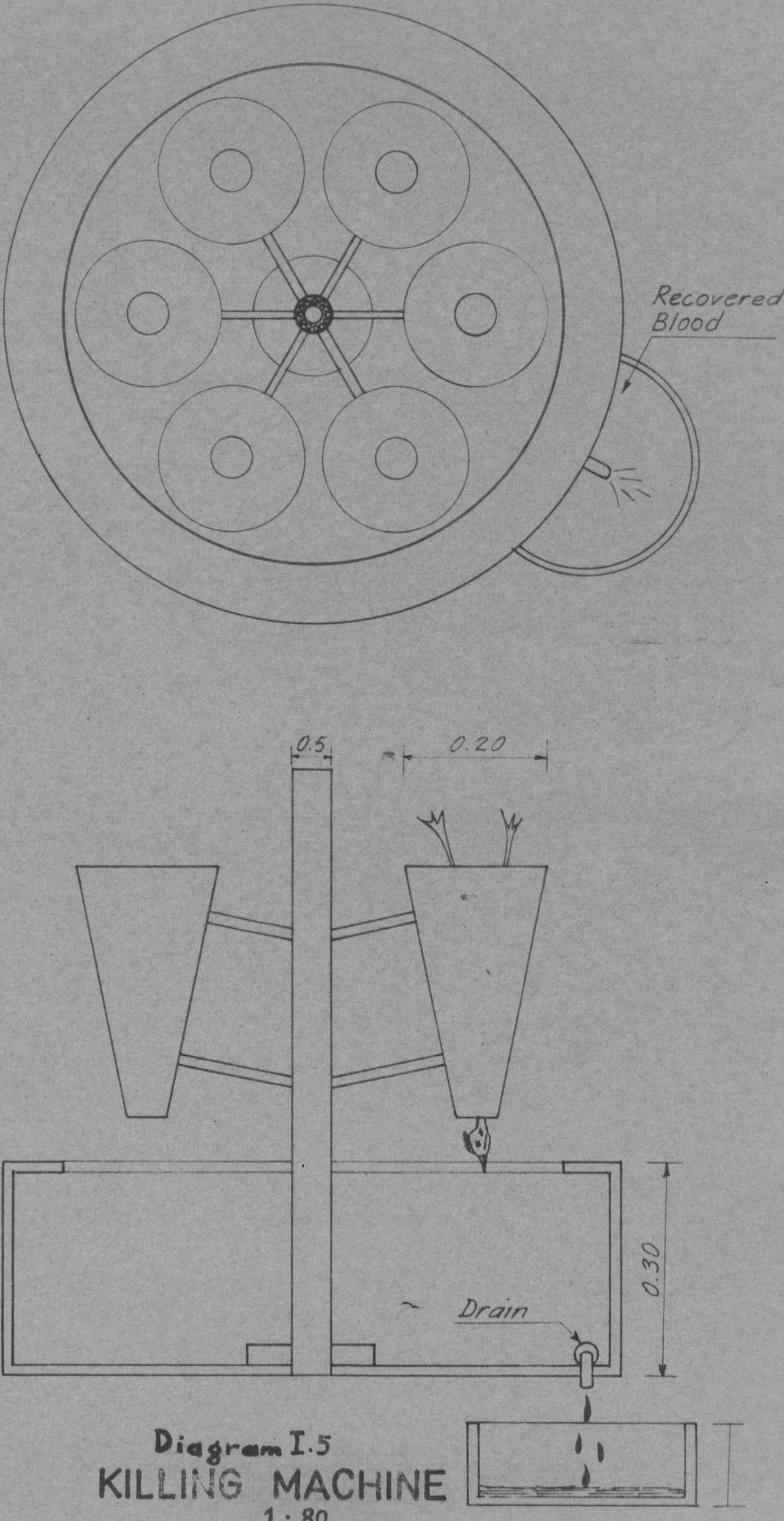


Diagram I.5

KILLING MACHINE

1 : 80

nated along with the feathers and the accumulated viscera.

(iii) Scalding. The birds are then passed to a scalding tank. The scalding process is intended to loosen the feathers from the skin of the poultry. The scalding tank takes 175 litres of water. The water is allowed in the tank and is heated by the use of a gas heater. The temperature of the heated water is regulated by a thermostat. The temperature of the heated water depends on the type of scalding required.[3] Heating of the water starts before the killing operation.

Actually, two types of scalding are practiced in Shuman's farm. One is called the semi-scald and the other the slack scald.

a) Semi Scald: The water is heated to a temperature of 128°F. The birds are kept at that temperature for 40-60 seconds. All outer skin is preserved. The processed poultry would look better when all the semi-scalding operations are over and hence will have a better marketable value.

b) Slack Scald: The water is heated to a temperature of 140-145°F and the birds are kept in the heated water for 30-40 seconds. Part of the skin is removed in this operation.

Shuman, however, prefers semi-scalding and uses it almost exclusively.

The scalding tank with a capacity of 175 litres is continually overflowing. Filling of the scalding tank is simultaneous with the overflowing discharge. At the end of the day's work, the scald tank is completely emptied in 15 minutes and is then usually washed.

The drained water from the scald tank contains residual blood not drained in the killing operation. The capacity of the scald tank is four to five birds put together.

(iv) Defeathering. Defeathering of the birds is done in a cyclic defeathering machine into which the birds are manually placed. The cyclic type machine is called a rougher and picker.[3] It consists of a counter-rotating steel drums with mounted rubber fingers 15 cm. long placed at about 10 cm. on centres.

At the end of the defeathering process the machine is stopped and it throws out the picked birds automatically into a collecting tub placed under the cyclic defeathering machine.

The present machine has a capacity of four to five birds per cycle.

(v) Pin-defeathering. This process consists of manual removal of pin feathers, which are small and fine feathers that are not removed by the defeathering machine.

(vi) Evisceration and cutting. Evisceration of the birds is done on a table by two laborors who handle the present volume of work adequately. The head and the lower portion of the bird are removed first followed by the removal of the inedible glands, pulling of the entrails, inspection of the carcass; recovery, trimming and washing of the heart, liver and gizzard; removal of the lungs, and recovery and washing of the neck.

The carcasses are then washed in tub near the evisceration table. There is no continous flow-away system for the washing process.

(vii) Chilling and Packing. Directly after washing, the carcasses are carried to an adjacent room for (1) chilling with ice and water, (2) refrigeration and (3) packing.

In chilling the animal heat is removed which is an important operation for packing. Chilling is done with ice and water in small tubs. The temperature of the chilled carcass reaches about 38-40°F. It has been noted by researchers that the flavor is improved by a thorough and quick chilling, as well as an increase in the marketable life.[3]

The carcasses are then put in a built-in refrigerator for drying. The moisture content of the packed birds affects: the marketing life of the bird and the weight of the bird which means that the consumer will pay for any excess water. The moisture content of the birds ranges from 8-10%.

The birds are then sorted out according to their weight and are packed. The packed birds are ready for delivery to the trucks leaving the processing plant. Otherwise, the birds are stored in the refrigerator for subsequent delivery.

2. New Installations

Figure I.6 shows the operation after the conveyor line system makes it quicker and easier to produce 3000 processed birds per day, because the unit can produce 600 birds per hour; and hence only five hours of operation will be necessary.

The anticipated change in poultry processing at Shuman's plant due to the introduction of the new system is outlined below, attention being given to current practices in plants in the United States:-

(i) Receiving. The birds are first suspended by their feet to shackles placed in a conveyor line, that runs at a convenient level for the killing operation.

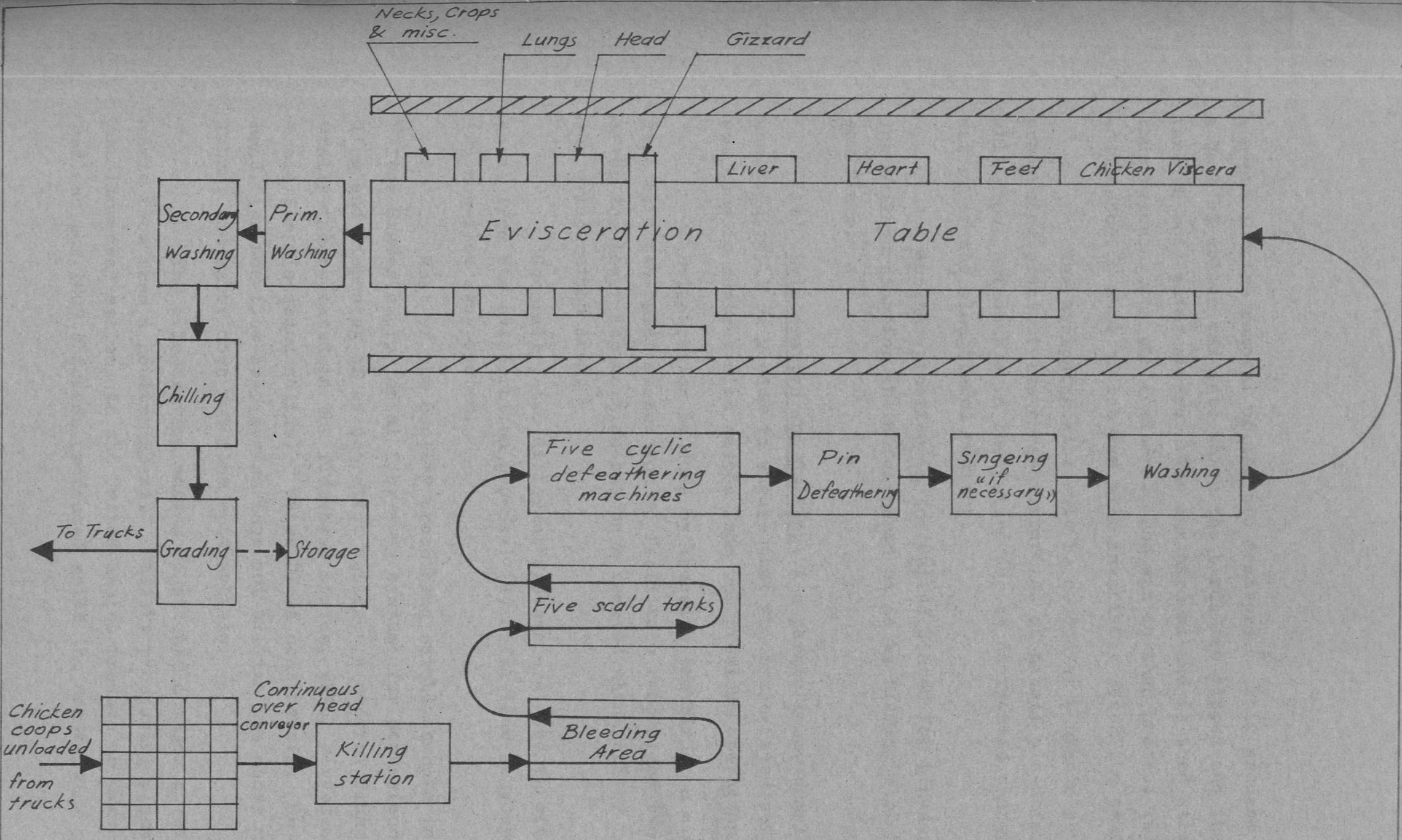
The rate of movement of the conveyor depends on the number of laborors in the plant, because laborors might not be able to cope up with a quick moving conveyor and vice versa. The number and size of the scalding tanks and the defeathering machines are also factors affecting the speed of the conveyor.

(ii) Scalding and Defeathering. No change is needed in these operations. The introduction of four more scalding tanks and cyclic type machines for defeathering will be necessary to scald and defeather respectively 3000 birds per day instead of the present 600 birds per day.

The mechanical line-type defeathering machine is more popular in the United States since it gives more output and is more flexible.[3] The cost of installing a line-type machine is not warranted.

(iii) Pin-defeathering. More laborors will be needed for this process. Otherwise, no other change is required.

In the United States "wax stripping" is somethimes used as



OPERATION LINE IN THE EXPANDED PLAN

a means for the removal of the pin feathers.[6] This process utilizes a bath of molten wax into which the birds are dipped and then passed through cold water sprays. The wax hardens and is then stripped off, thus removing the pin feathers. The wax is then heated, filtered and reused.[6] Some of the wax will invariably reach the sewer.

Wax stripping will only be needed at Shuman's poultry processing plant if the present practice of manual pin-defeathering will prove unfeasable in the future due to unexpected changes in the nature of the slaughtered poultry.

Another practice in the United States for pin-defeathering employs singeing the defeathered birds by flaming with an arc gas flame.[6]

(iv) Evisceration and Cutting. A separate room, completely enclosed, will be needed to ensure that the eviscerated poultry do not come in contact with wastes from the previous operation.

Evisceration is done by trussing the birds on a conveyor line by a two-point suspension to facilitate removal of the viscera, after the lower leg portion has been removed when poultry reaches the evisceration area.[3]

Generally, two different systems are used in offal disposal from the evisceration process: (1) offal-flow away system (2) non-flow away system.[6]

Most of the poultry processing establishments in the United States employ offal flow-away systems for convenience in handling and disposing of evisceration wastes.[3] A central flume is generally incorporated in the flow-away system, which serves as a receptacle for discarded solids.[2] Water flows continously. On the other hand, the non-flow-away system does not utilize the above mentioned flume; and water does not flow continuously.

The evisceration wastes constitute a major portion of total waste flow from a poultry plant.[3] Poultry processing plants employing the flow-away systems in the United States produce an average of 7000 gallons per 1000 chickens processed while the non-flowing produce only

4500 gallons per 1ooo chickens.[3,6]

The non-flow away system will continue to be employed at Shuman's poultry processing plant for saving as much water as possible.

(v) Chilling and Packing. No change is warranted except the increase of the chilling tubs used at present.

C. POULTRY PROCESSING WASTES

In order to design a waste treatment plant for Shuman's poultry processing plant in Beit Miri, it is essential to study the sources and characteristics of the liquid wastes derived from each source. The characteristics of the total mixed liquor reaching the sewer is discussed separately in Chapter II.

1. Receiving Area

Manure, feathers and dirt are deposited on the floor of the receiving area. At present the live poultry are kept in the receiving area for a short period and hence this source is of minor importance since the quantities of manure, feathers and dirt are small.[3]

The floor of the receiving area is dry cleaned daily to reduce the pollutional effect of the waste from the receiving area. Part of the manure, feathers and dirt will invariably reach the sewer, even after the floor is dry cleaned. This part is mainly produced in the clean-up period.

A report on dry cleaned floors of the receiving area indicates an average of five pounds of BOD per 1000 chicken and six pounds of suspended solids.[3] It is hence expected that BOD and suspended solids values from the receiving area at Shuman's poultry processing plant are of the same order (5 lbs BOD /1000 chickens; and 6 lbs suspended solids/1000 chickens).

2. Killing.

Blood, the constituent of the waste in the killing process, is the waste of greatest pollutional strength in poultry processing.[1,3] Blood recovery is just a measure to decrease the BOD and suspended solids and other pollutional strengths.

It is estimated that about 15% of the drainable blood of the chicken reach the sewer because of spills in the operation of blood recovery and because of splashes from the killing operation. This figure was arrived at by approximately estimating the average amount of blood from one chicken as follows:-

It is reported that about 8% of the body weight of the chicken is blood, of which only 70% is drainable and 30% undrainable blood that reaches the scalding tank.[3,6]

Average body weight of chicken = 1280 gm.

Estimated weight of blood/chicken = $\frac{8}{100} \times 1280 = 102.4$ gms.

Drainable weight of the blood = $\frac{70}{100} \times 102.4 = 72$ gms.

Undrainable blood reaching the scalding tank = 102.4 - 72 = 30.4 gms. Measured part of drainable blood reaching sewer/chicken is approximately 10 c.c. (approximately 10 gms. of blood).

Percentage of total blood reaching the sewer is $\frac{10}{72} = 15\%$. On that basis the estimated percentage of blood was approximated at 15% of drainable blood. Shuman estimates the percentage of blood at 10 - 15% of drainable blood.

The effect of blood recovery on the BOD and suspended solids of the liquid wastes from Shuman's poultry processing plant will be discussed in Chapter II under BOD, and suspended solids, respectively.

The BOD and suspended solids of waste waters of similar poultry processing plants using blood recovery methods, are generally within the range of 22.8 - 23 pounds of BOD per 1000 chickens and 12 - 12.2 lbs of suspended solids/1000 chickens. If no reasonable blood recovery measures are taken, the BOD and suspended solids values may reach 35 - 40.4,[3,6] and 17.8 - 21.0 pounds/1000 chickens, respectively. The difference is solely due to blood recovery.

The extent to which blood recovery can take place depends on the time of drainage and method of collection.[3] One to two minutes are usually allowed at Shuman's Poultry Processing Plant for the drainage of the blood. Bolton [7] reported that a longer time of drainage of the blood makes the defeathering of the birds more difficult.

At the completion of the operations, the recovered blood collected in troughs is disposed by inciniration together with the wastes from the evisceration process. At present this is done in a dump area near the slaughter house, located as indicated on the layout plan shown in Appendix I. A recently installed incinerator is adequate for handling the wastes of the estimated future production of 3000 processed birds per day.

3. Scalding

The volume of waste water produced is estimated at one third gallon per bird because an average of one-quarter to one-half gallon is needed for scalding.[7,3] In metric units the flow from the scalding tank is then 1.20 litres/bird or 1200 litres/1000 chickens.

The scalding tank receives that part of the blood that did not drain in the killing operation, and some manure and miscellaneous dirt that may wash from the feathers.[3,6,7] It may also have a considerable amount of feathers. Anderson et al [4] emphasize the high pollutional strength of the waste from the scalding tank.

4. Defeathering

Water is not used in the defeathering process except to clean the cyclic defeathering machine. The feathers are swept from the floor and put into a container. The feathers are then incinerated in the dump near the slaughter house and the ashes are buried under ground. Even with the most efficient handling of the feathers, some eventually reach the sewer. They present a nuisance to the treatment of poultry processing wastes because they tend to clog pipes, valves and other appurtenances. In addition, feathers are of such complex organic nature that they are not biologically decomposable.[5] The chemistry of the feathers is discussed briefly in Chapter II.

5. Evisceration and Cutting.

The solid wastes produced at the evisceration table consist of feet, heads, inedible viscera, crop, wind pipes, sand grit, flesh trimmings, grease, fat and blood.[4,6]

These solid wastes are directly removed in barrels to the dump for incineration together with the recovered blood and the feathers.

Water taps are opened frequently for washing the carcasses while the evisceration process is taking place. These operations are the largest contribution to the volume of water in the poultry processing plant.

Many reports[3,6] indicate that the expected discharge from evisceration, in cases where waste solids are collected in separate containers, is six to eight pounds of BOD per looo chickens processed. In Shuman's poultry processing plant the concentration of BOD in the discharge from eviscerated wastes is expected to be higher than the concentration of BOD in the reported plants since the water consumption in Shuman's plant is only 8330 litres per 1000 chickens (2200 gallons/1000 chickens) while the average consumption reported in the literature cited ranges from 2600 gallons to 4500 gallons per 1000 chickens.[3,6,7]

6. Chilling, Packing and Clean-up.

About 1500 litres of water per 1000 chickens[3,7] are the estimated needs for the chilling operation at Shuman's poultry processing plant.

Wastes from chilling operation contain some fat, bits of flesh and other solids, and is generally of low pollutional strength.[3]

No record is available in the literature of the pollutional strengths of waste water from the chilling operation.[3]

Floor clean up is done at the end of the day's work. The floor washings include the remaining blood, dirt, manure, feathers and cuttings. The BOD of wastes from cleaning operation alone is reported in plants similar to Shuman to be 10.2 lbs/1000 chickens.[7]

Only 200 gms of detergents are used daily for clean-up. With a present daily flow of 5000 litres, the average concentration of the detergent is 40 mg/l. The use of detergents in clean-up operations has not caused any operational trouble in the existing septic tanks and in the infiltration pit. The Taft report[3] states that no information is concluded on the effect of detergents on poultry wastes. However, no operational problem is anticipated due to detergents in the treatment of wastes from the Shuman plant.

CHAPTER TWO

CHARACTARISTICS AND ANALYSIS OF THE WASTES

A. GENERAL CONSIDERATIONS

To propose any treatment for any kind of waste waters, the knowledge of the physical, chemical and biological characteristics of the wastes is a fundamental prerequisite. The ultimate aim of the treatment is to produce an effluent which is of acceptable characteristics from the sanitary point of view.

The poultry processing wastes are mainly organic substances;and with the exception of feathers, all the organic matter found in poultry processing wastes are decomposable by aerobic bacteria in the presence of oxygen as shown in the equation:[8]

$$\text{Organic matter} + \text{bacteria} + O_2 \longrightarrow CO_2 + NO_3^- + SO_4^= + H_2O$$

Since the waste waters include only blood, manure, feathers and dirt, some of which are recoverable, the separation of the waste water of any process from any other is not warranted.[5] The pollutional strength of the waste waters with their content of organic matter is different from one process to the other.[7] Mixing of the wastes from different sources takes place on the floor.

Variation in the characteristics occurs: (1) When the scalding tank is completely emptied at the end of the day's work. Some of the blood, dirt, manure attached to feathers and some feathers are washed away after scalding process is over.[6] These settle in the scalding tank and are discharged into the sewer by the liquid waste that is continuosly overflowing from the scalding tank. (2) The variation in characteristics of the poultry processing waste happens during the clean-up period, because varying intensities of the wastes find their way to the sewer during the clean-up operation.[3]

B. ANALYSIS

Chemistry of Components of the Waste

The mixed liquor reaching the sewer is composed of water, blood, feathers, manure, dirt and flesh trimmings.

A brief discussion of the chemistry of these components of the waste water, in as far as it concerns the waste water treatment, is appropriate, so that the effect of all possible treatments can be evaluated.

1. Water Supply.

Water is supplied directly from the mains of Beit Miri municipal water system. Another source utilized in summer is a storage reservoir that collects water in winter.

An important impurity in the water is the presence of the sulfate ion which is utilized by anaerobic bacteria for the production of odours due to H_2S which may also cause sewer corrosion.[8] Odours due to H_2S were distinctly perceptible in the samples of waste water collected from Shuman's poultry processing plant after a period of storage of three days in closed bottles. Chemical reactions are as follows:-

$$SO_4^{--} + \xrightarrow[\text{bacteria}]{\text{anaerobic}} S^{--} + H_2O + CO_2$$

$$S^{--} + 2H^{+} \rightleftharpoons \underline{H_2S}$$

2. Blood.

Blood consists of plasma in which the cells float. The main constituents of the plasma are proteins - albumin and globulin, anions - mainly bicarbonates and chlorides, cations - mainly sodium and lesser concentrations of potassium, calcium and magnesium.[9] Blood cells contain the red coloring hemoglobin which plays a role in the pH of the blood.[9]

Animal blood is slightly alkaline with a pH of about 7.4.[10] It is buffered by means of its content of weak acids, alkali salts the principal one of which is sodium hydrogen carbonate, and proteins.

Of the total volume of the blood, proteins represent over 20%. The plasma contains 10% by weight of solids, of which 7-9% are proteins, 1% salts and the rest various other substances.[11] When dry, blood contains 11.8% of N and 1.2% of P.[12]

3. Feathers,

are among the most remarkable of organic structures as far as variety, complexity of structure and function.[11] Feathers are composed of keratines, which is a sub-division of proteins.

Feathers reaching the sewer are generally lighter than water and hence constitute a floating problem in sedimentation tanks, if screening does not stop the feathers from reaching the sedmentation tanks.[5]

4. Manure, dirt and flesh trimmings.

These are mainly nitrogeneous organic matter. Micro - organisms attack the nitrogeneous components and the more readily fermantable carbohydrates.[16]

The proteins which are nitrogenous compounds, and other organic compounds present in manure, dirt and flesh cuttings are better discussed when the whole waste is considered.

LABORATORY TESTS

1. Tests for the Determination of Characteristics.

Determination of the characteristics of the mixed waste from the poultry industry require the following essential tests: 5-day, BOD, suspended solids,dissolved solids, volatile solids, settleable solids, total alkalinity, total nitrogen and pH.[3,6] Porges[6] report does not include total nitrogen as a necessary test while it includes the turbidity test. The Taft report[3] includes the COD test, because experience has shown that correlation factors can be established between the BOD and the COD[8]. In addition the COD requires only three hours for determination.[13]

The performed tests on samples from the wastes of Shuman's poultry processing plant are: The 5-day BOD, suspended solids, dissolved solids, volatile solids, settleable solids, total alkalinity, total nitrogen and pH. A comparison with the values given for the above mentioned tests with values given in the literature is necessary.

2. Sampling.

Table II.1 shows the dates and locations of sampling as actually taken from the Shuman plant at Beit Miri:-

TABLE II. 1.

Sampling Locations

Date	Sample No.	Location	Remarks
2 Jan. 64	1*	At screen enroute to sewer	Mixed liquor
2 Jan. 64	2	Wastes from scalding tank over flow	Collected at floor
2 Jan. 64	3	Outlet at bottom of septic tank.	Waited till color of waste became uniform
2 Jan. 64	4	Effluent from percolation pit.	Taken from overflow
15 Jan. 64	5*	At screen enroute to sewer	Mixed liquor (same as No.1)
20 Jan. 64	6*	At screen enroute to sewer	Mixed liquor (same as No.1)
10 Feb. 64	7*	At screen enroute to sewer	Mixed liquor (same as No.1)

* Collected from the same location at the screens enroute to sewer.

Properly cleaned soft drinks bottles and special glass bottles were used for sampling. Care was taken not to include the larger feathers and flesh trimmings that can be stopped by screens at the end of the gutter in the slaughter house.

The existing percolation pit, used at present for disposal of the poultry processing wastes was already percolating near the top of the pit to the ground surface.

In the text reference will be made to the samples by the numbers shown in Table II.1

3. Results and Interpretation.

(i) pH: Results of the pH measurements are shown in Table II.2.

TABLE II.2

pH Values

Sample No.	pH	Remarks & Interpretation
No.1	6.0	pH of the waste waters is affected by pH of the process water.
No.2	6.4	
No.3	6.0	
No.4	6.0	
No.5	6.0	
No.6	6.2	
No.7	6.2	

Reports on pH of poultry processing waste indicate a range of 6.5 -9.0,[3] while another report gives a range of 6.7-7.6.[7]

pH is an important factor affecting the coagulation and digestion processes for treatment of wastes.

(ii) Alkalinity.

The alkalinity test was done on samples 1,2,3,4 and the results are given in Table II.3

TABLE II.3

Alkalinity Tests

Sample No.	Alkalinity mg/L of $CaCO_3$		
	Carbonate	Bicarbonate	Total
1	0	400	400
2	0	400	400
3	0	400	400
4	0	400	400

Remarks and Interpretation.

Porges[6] reports that the alkalinity in the water supply over shadows the amounts produced during the processes. It is noticed that the alkalinity of the various samples was exactly the same.

Alkalinity is an important factor in the coagulation process. Chemicals used for coagulation react with water to form insoluble hydroxide precipitates. The released H^+ ion reacts with the alkalinity of the water which acts as a buffer maintaining the pH within a range in which the coagulant can be effective.[8]

The Taft report[3] indicates a range for total alkalinity of poultry processing in waste waters of 40-350 mg/L of $CaCO_3$. Another study of five different poultry processing plants indicates, a range equivalent to 45-295 mg/L;[7] while another report indicates 11.8 lbs of alkalinity per 1000 chickens.[4] The total alkalinity of 400 mg/L in Shuman's poultry processing waste is equivalent to 7.4 lbs/1000 chickens.

(iii) Turbidity.

Waste water from the poultry processing plant contains lots of organic matter and bacterial growths that add greatly to the turbidity of the water.[14]

Table II.4 shows the results of turbidity tests.

TABLE II.4

Turbidity Tests

Sample No.	Turbidity Units	Method of testing
1	600	Jackson candle turbidimeter was used.
4	350	

Interpretation.

The difference in turbidity between sample No.1, taken at screen, just leaving to the sewer, and sample No.4, the effluent from the percolation pit, is just an index of the organic character of the effluent in comparison with that of the influent waste waters.

Porges[6] reports turbidity values ranging between 500-2200 ppm for five different plants studied. Another report indicates an average of 34.40 lbs of turbidity per 1000 chickens.[4] In Shuman's plant, the turbidity of 600 ppm is equivalent to:-

$$\frac{600 \times 2200 \times 8.34}{10} = 11.0 \text{ lbs of turbidity per 1000 chickens.}$$

The value for water consumption of 2200 gallons/1000 chickens is used in the above calculation.

It is noticed that the turbidity of 600 mg/L of $CaCO_3$ is on the low side of the range of 500-2200 mg/L given by Porges.

(iv) BOD.

The BOD test is the major test done on waste waters from the Shuman's poultry processing plant, because this test determines the pollutional strength of the waste.[8,15,16]

Table II.5 shows the results of BOD tests.

TABLE II.5

BOD tests

Sample No.	Location	BOD	Remarks
1	At screen enroute to sewer	1420	Mixed liquor collected at the screen
5	At screen enroute to sewer	1550	
6	At screen enroute to sewer	1620	
7	At screen enroute to sewer		
3	Taken at bottom of septic tank	640	taken on same date as sample No.1.
4	Effluent of percolation pit	360	taken on same date as sample No.1.

The indicated values of BOD are not the averages of BOD values found from the different percentages of dilution. It is not good practice to take the arithmetic average BOD values from the different dilutions, because statistically chances are that one value is more reliable than the other.[8] To find the most reliable value for BOD, Sayer suggests to find the BOD value due to the increment in depletion of oxygen between two dilutions of the tested sample. This increment is due to an increment in the dilution of sample, and the closest value of BOD to the calculated figure is the most reliable value. BOD figures shown in Table II.5 are based on this suggestion. A sample calculation is shown in Table II.6

TABLE II.6

Sample Calculation for Determining most reliable BOD value.

Sample No.	Percentage of Dilution	Depletion of DO	BOD
1	0.2 % 0.5 %	3.2 mg/L 7.1 mg/L	1600 mg/L 1420 mg/L
Increment in % Dilution = 0.3 % Increment in Depletion of DO = 3.9			BOD = $\frac{3.9}{0.3}$ x 100= 1300 mg/L

Hence the value of 1420 mg/L is more reliable because it is close to 1300 than the 1600 mg/L.

Average value of BOD of waste water enroute to sewer: The average value of BOD of the samples 1,5,6,7 collected at the screen leaving to the sewer is 1520 mg/L. The BOD of poultry processing wastes is usually interpreted as pounds of BOD per 1000 chickens.[7,14] For that purpose the average BOD of 1520 mg/L is converted to pounds per 1000 chickens processed to simplify comparison with established figures in the literature:-

Average flow per 1000 chickens = 8330 liters
= 2200 gallons

$$\text{Pounds of BOD per 1000 chickens} = \frac{1520 \times 2200 \times 8.34}{10^6} = 28.0 \text{ lbs.}$$

Interpretation.

Table II.7 presents the average values of BOD of poultry processing wastes as were given in references shown in Column 2, indicating the difference in values in flow-away and non-flow away processes. The flow-away process produces more gallons of waste water per 1000 chickens than the non-flow, as is shown in Table II.7.

TABLE II.7

Comparison of BOD values for different poultry processing plants.

Ref. No.	Researcher	Type of plant	Waste water flow Gal/1000 chickens.		B O D mg/L		B O D lbs/1000 chicken			Remarks
3	The Robert A. Taft report	non-flow-away	4500				23			With blood recovery.
							35			All blood wasted.
		Flow-away	7000				25			With blood recovery.
		In general			150-2400					Range of both types of plants
6	Ralf Porges	Full pack	3400*		1230*					Some blood to sewer.
17	Budd & Crawford				1047					Non-flow-away
7	Bolton		Process water	Clean-up water	P	C	P	C	Tot.	Remarks
		A (non-flow-away	1600	1000	961	1205	12.6	10.2	22.8	Similar to Shuman's plant blood recovered.
		B (flow-away)	7500	5000	262	296	16.3	11.1	27.4	Rorary screen used blood recovered.
		C (flow-away)	6000	1800	377	271	14.3	3.9	23.2	Rotary screen used blood recovered.
		D (flow-away)	2600	1100	860	796	18.4	6.4	24.8	Rotary screen used blood recovered.
		E (no blood recovery	3900	1300	1430	318	37.2	3.2	40.9	Only caogulated blood on floor is recovered.
4	Anderson & Koplovsky	Partial blood recovery			40.20	lbs.	of BOD/1000 ch.			2/3 of blood enters sewer
14	Nemerow, N.L.	not mentioned	32600		30	″	″ ″ / ″ ″			Total liquor

* = These values are calculated from the two given figures,one is for killing and the other for eviscesation and packing.

The total mixed liquor from Shuman's poultry processing plant was found to have an average BOD value of 1520 mg/L or 28.0 lbs of BOD per 1000 chickens. This compares favourably with non-flow plant producing 23 lbs of BOD per 1000 chicken,[3] where the plant in question uses the same non-flow away system of poultry processing as used at Shuman's plant.

The 28 lbs of BOD/1000 chickens also compares favorably with the 22.8 lbs of BOD/1000 produced at Bolton's[7] plant type non-flow-away plant, which is very similar to Shuman's poultry processing plant. Plant A, consumes a total of 2600 gallons of water per 1000 chickens of which 1600 gallons is for processing water and 1000 gallons for clean-up. Concerning waste water production this plant is the closest to Shuman's poultry processing plant. The average BOD from the processing and clean-up operations is calculated as follows:

BOD in mg/L in total waste from Plant A =

$$\frac{22.8 \times 10^6}{2600 \times 8.34} = 1060 \text{ mg/L}$$

This BOD value of 1060 mg/L is considered close enough to the average BOD value of 1520 mg/L obtained at Shuman's plant, especially considering the fact that Shuman's plant consumes 400 gallons less than plant A per 1000 chickens. Plants B, C and D of Bolton produce 27.4, 23.2 and 24.8 lbs of BOD per 1000 chickens respectively, on which basis the value of 28.0 lbs of BOD per 1000 chickens for total wastes from Shuman's poultry processing plant is acceptable since plants A, B, C and D and Shuman's plant are all of the non-flow-away system. However concentration values of BOD in mg/L in Plants B, C and D show a great difference from the esablished value of 1520 mg/L because of the high water flows used there (see Table II.7).

Effect of Blood Recovery.

Blood recovery has a great effect on the BOD value of the total wastes from poultry processing plants in general.[3,6,7] The following estimates the effect of blood recovery on the BOD loading of wastes from Shuman's poultry processing plant.

In Chapter I, it was established that the drainable blood constitutes an average of 72 gms per chicken of which approximately 15% reaches the sewer i.e. 85% of the blood is recoverable.

Thus $\frac{15}{100} \times 72 =$ 10.80 gm of blood/chicken reach the sewer
or 10.80 x 1000 = 10,800 gm of blood/1000 chickens

Recovered blood =72 - 10.8 = 61.2 gms/chicken
=61,200 gm/1000 chickens

Chicken blood is estimated to have a BOD value of 92,000 mg/L.[6,7]
Bates[18] estimated chicken blood to have a BOD value of over 100,000 mg/L.

Fair and Gayer[15] estimates meat packing house blood to have a BOD of 165,000 mg/L.

The average BOD value of 100,000 mg/L is used in this presentation:

$$\text{Recovered BOD due to blood recovery} = \frac{100{,}000}{1000{,}000} \times 61{,}200 = 6{,}120 \text{ gm}$$

= 13.5 lbs of BOD per 1000 chickens.

Bolton reported that plant BOD can be reduced by 15 pounds per 1000 processed chickens, if reasonable blood recovery measures are taken. Others report a reduction of 14 pounds of BOD per 1000 chickens. Plant E, shown in Table II.7 does not utilize blood recovery measures except on coagulated blood on the floor. It shows a BOD of 40.4 lbs per 1000 chickens while the average BOD from plants A, B, C and D utilizing blood recovery measures show on average of 24.5 lbs/1000 chickens. Thus due to blood recovery alone 15.9 lbs of BOD per 1000 chickens were recovered on the average in Bolton's plants A, B, C and D.

If no blood recovery measures were taken at Shuman's poultry processing plant, and assuming that all blood reaches the sewer, the effect on BOD of blood draining in the killing operation would be:

$$72 \times 1000 \times \frac{100{,}000}{1{,}000{,}000} = 7200 \text{ gm} = 15.8 \text{ lbs of BOD/1000 chickens}$$

(v) Solids.

Together with the BOD, the suspended solids, dissolved solid and settleable solids are considered major criteria in the design of treatment plants for the poultry processing plants in particular, and for industrial wastes with organic effluent in general.[16] The degree of pollution of the waste increases with the amount of suspended matter.[16] Measurement of suspended solids is considered fully and as significantly as BOD since deposition of such solids is expected to occur through biological and chemical flocculation.

Results of solids for waste waters from Shuman's poultry processing plant are given in Table II.8.

TABLE II.8

Solids of waste waters of Shuman's plant

Sample No.	Type or location	SOLIDS					Remarks
		Suspended mg/L	Dissolved mg/L	Volatile mg/L	Total mg/L	Settleable mg/L	
1	mixed liquor	850	1308	1540	2158	6.0	taken at screen
7	mixed liquor	872	1343	1586	2215	8.0	taken at screen
3	taken at bottom of septic tank	410	671	690	1081	2.0	taken on same date as sample No.7
4	effluent of percolation pit	265	247	298	512	1.5	taken on same date as sample No.7
Average values of mixed liquor samples 1 & 7	Suspended solids of total mixed liquor = 861 mg/L Dissolved solids of total mixed liquor =1326 mg/L Volatile solids of total mixed liquor =1563 mg/L Settleable solids = 7.0 mg/L						
Samples 3 and 4 show solids from waste water after present treatment.							

Interpretation.

Conversion of concentration figures into pounds of solids per 1000 chickens is necessary for comparison with reported figures established in the literature.

Considering an average flow of water of 2200 gallons per 1000 chickens the average values for solids will be:-

Suspended solids: $\frac{861}{10^6} \times 2200 \times 8.34 = \underline{18.4}$ lbs/1000 chickens

Dissolved solids: $\frac{1326}{10^6} \times 2200 \times 8.3 = \underline{24.3}$ lbs/1000 chickens

Volatile solids: $\frac{1563}{10^6} \times 2200 \times 8.3 = \underline{28.8}$ lbs/1000 chickens

Table II.9 shows the reported values of suspended, dissolved, volatile, and settleable solids of various poultry processing wastes.

TABLE II.9

Comparison of Solids in Waste Waters of Poultry Processing Plants.

Ref. No.	Researcher	Type of plant	Waste water flow gal/ 1000 chick.	Suspended solids		Dissolved solids		Volatile solids		Settleable solids
				mg/L	lbs/ 1000 chic	mg/L	lbs/ 1000 chs.	mg/L	lbs/ 1000 chs.	mg/L
3	The Robert A Taft Report	non-flow	4500		12 21					
		flow-away	7000		13 23					
		in general		(100-1500)		(200-2000)		(250-2700)		1-20
6	Ralf Porges	full pack	3400 @	1180@						
17	Budd & Crawford			312		673				
7	Bolton	A) processing	1600	555	7.2	767		1031		5.0
		clean-up	1000	641	5.0	1742		1450		5.0
		total	2600		12.2					
		B) processing	7500	154	9.7	286		336		1.6
		B) clean-up	5000	93	3.8	522		431		1.0
		B)total	12000		13.5					
		C)processing	6000	192	9.4	282		393		-
		C) clean-up	1800	192	2.8	387		403		3.4
		C) total	7800		12.2					
		D) processing	2600	428	9.3	594		836		2.5
		D) clean-up	1100	267	2.3	955		905		3.0
		D) total	3700		11.6					
		E) processing	3900	489	15.7	1068		1259		13.4
		E) clean-up	1300	192	2.1	488		432		2.1
		E) total	5200		17.8					
14	Nemerow, N.L.	not mentioned	3260		15.3		11.3*			

@ : These values are calculated from two given figures: one for killing and the other for evisceration and packing.

* : Calculated from difference between total solids and suspended solids.

N.B: remarks given in Table II.7 - Col.6 apply for the plants reported in

(vi) Total Nitrogen.

Table II.10 shows the results obtained for the total nitrogen values of the poultry waste waters from the Shuman's plant:-

TABLE II.10

Total Nitrogen

Sample No.	Type	Total Nitrogen mg/L
1	mixed-liquor	218
7		202
Average value		210

Interpretation.

For design purposes the determination of total nitrogen is usually used to support the BOD determination, since both determine in different terms the strength of organic matter present. However, under aerobic treatment the operational costs can be kept at a minimum by controlling nitrification.[16] Total nitrogen determination is important to determine whether enough available nitrogen is present for aerobic biological treatment.

Table II.11 gives two values of total nitrogen for slaughter house wastes the second of which is the total nitrogen for meatpacking house waste waters which are similar to poultry processing wastes in characteristics.

TABLE II.11

Comparison of total nitrogen in slaughter house waste-waters.

Ref. No.	Researcher	Type of Plant	Average Flow	Total Nitrogen	Remarks
3	The Taft Report	Poultry processing plants in general	4500-7000 gallons per 1000 chickens	15-300 mg/L	The higher limit is expected when no blood-recovery measures are taken
19	Babbit	Packing house wastes	4300 gallons per ton of hogs	3.15 lbs per ton	This value is just for comparison

Babbit's[19] figure of 3.15 lbs of BOD per ton of hogs is used only for comparison. The concetration for the mentioned BOD is 88 mg/L :- $\left(\frac{3.15}{4300 \times 8.34} \times 10^{6} \right)$.

The total N value of 210 mg/L compares reasonably with both of the reported values in Table II.11.

(vii) Grease.

The determination of grease was not done by laboratory but the values given in the literature present a more favorable picture of the characteristics of poultry wastes in general. Very few references give a laboratory determined estimates of the grease usually found in poultry processing wastes.

Nemerow[14] states that the average value of grease in poultry processing wastes is in the order of 1.3 lbs per 1000 chickens. Grease is an important factor in primary treatment because it can produce a difficult flotation problem in sedimentation tanks. However, the effect of grease poultry packinghouse wastes is not appreciable and should not be over emphasized.

CHAPTER THREE

TREATMENT OF WASTE

A. PRESENT TREATMENT

General.

The nature of the processing operations and of the waste produced in these operations should provide at this stage the proper index for waste treatment. To start with, the present treatment employed at Shuman's poultry processing plant in Beit Miri is discussed in as much as it throws light on the proposed treatment after the expansion has taken place.

1. Summary of Basic Data.

(i) Commencement of operation: Summarizing the basic data of Shuman's plant: The plant in Beit Miri started in July 1963.

(ii) Capacity of plant: The capacity of production at present is 600 birds per day, 6 days a week.

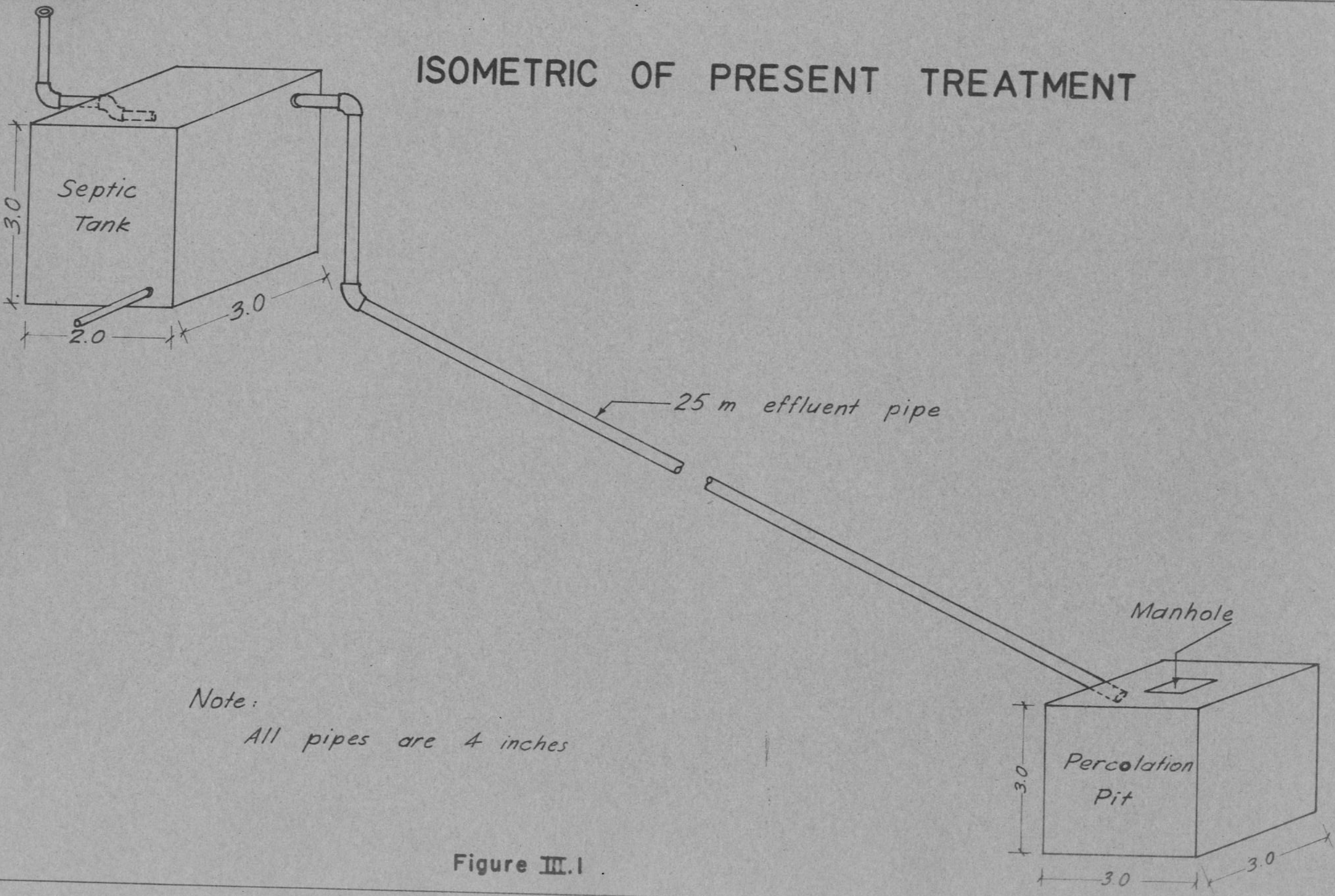
(iii) Water consumption and volume of liquid waste: The average volume of water used at present is 5.0 m^3 per day or an equivalent of 8.33 litres per bird. It is assumed that all of this amount reaches the sewer since only extremely small and in significant amounts may be used for purposes other than processing including infrequent washing or drinking.

(iv) Working hours: 5 hours per day. The production is uniform throughout the year.

2. Treatment Units Employed at Present.

(i) Description: The present treatment of the wastes from Shuman's poultry processing plant is shown schematically in Figure III.1.

ISOMETRIC OF PRESENT TREATMENT



Note:
All pipes are 4 inches

Figure III.1

There are essentially two units for the treatment of the wastes from Shuman's poultry processing plant:

a) A septic tank with the following dimensions 3.0 m x 2.0 m x 3.0 m.

The septic tank is built of concrete and has a flow-away pipe 4.5 inches in diameter at the bottom to relieve the tank of its liquid load when the system becomes over loaded. This is done usually once every week. The flow-away from the septic tank is allowed to flow over ground and is left there to dry off.

b) An infiltration pit with the following dimentions 3.0 m x 3.0 m x 2.5 m.

The connecting pipes are cast-iron and their dimensions are given in Figure

The infiltration pit is dug in rock. The sides are concreted to a depth of only 1.0 m. The effluent infiltrates through this pit regularly and it was found from experience that it over-flows in one to two months of operation.

(ii) <u>Efficiency of Present Treatment</u>: Laboratory tests were done to the efficiency of the present treatment. Samples from the influent to the septic tank, from the flow-away of the septic tank and from the infiltrating effluent were examined for BOD and suspended solids, turbidity and alkalinity reductions. The pH for waste water from each unit was also measured.

Results are shown in Table III.1

TABLE III.1

Efficiency of Present Treatment.

Test	influent (plant)	septic tank		effluent	infiltration pit	Total reduction
	mg/L	mg/L	% reduction	mg/L	% reduction	
B.O.D.	1420	640	54 %	340	47%	76 %
suspended solids	850	590	29 %	445	23%	47 %
Turbidity	600	490	17 %	350	29%	41 %
Alkalinity	400	400	0 %	400	0%	0 %
pH	6.2	6.0	3 %	6.0	0%	0 %

The results show clearly that the treatment employed at present is not satisfactory, for a BOD value of 340 mg/L in the effluent is in the order of values for untreated domestic sewage which indicates the need for more efficient treatment. Similarly, the suspended solids of the effluent is even higher than that of normal domestic sewage. The indicated total efficiencies for the removal of BOD, suspended solids and turbidity are low if compared with efficiencies obtained by conventional methods.

B. FUTURE EXPANSION

General.

It was stated that the purpose of this project is to select and design a treatment method for the liquid wastes from Shuman's poultry processing plant after the plant has expanded to produce an estimated 3000 birds per day 6 days a week. For such a purpose and in the light of all the information given so far, the basic design criteria should now be given.

1. Basic Design Data.

(i) Capacity.

The trend in production increase since the proprietor started operating his plant in Bekka in 1955 till now is found useful for explaining the reasons that the proprietor has in increasing his production from 600 birds per day to 3000 birds per day in his plant at Beit Miri.

Table III.2 shows this trend:

TABLE III.2

Processed Birds in Shuman Poultry farms.

Plant	Year	Production of processed birds (average No./day)
Bekaa	1955	23
Bekaa	1956	42
Bekaa	1957	84
Bekaa	1958	128
Bekaa	1959	163
Bekaa	1960	208
Bekaa	1961	337
Bekaa	1962	245
Bekaa	Jan.1963-Dec.63	400
Beit Miri	July-Dec.1963	600

In 1955 the Bekaa plant produced 7000 birds per year while both plants produced about 300,000 birds in 1963 of which about 87,000 birds were produced in Beit Miri plant starting July 1963.

(ii) Volume of Waste-Waters Produced.

The volume of waste-water produced was assumed to be equal to the water used.

The water consumption of 8330 litres per 1000 processed birds is mush on the low side when compared with figures in the literature as shown in Table III.3 for non-flow-away processing plants.

Figures for flow-away system are given just for comparison.

TABLE III.3

Water Consumption in Poultry Processing.

Ref. No.	Reference	Plant	Type	Waste Water Production per 1000 birds		Remarks
				Gallons	Liters	
3	The Robert Taft Report	13 different plants.	non-flow away	4500	17,100	Average values
			Flow-away	7000	26,600	Flow-away gigure given comparison only
6	Ralph Porges	C	-	3430	12,900	Calculated from given table.
7	Bolton	A (Plant similar to Shuman's)	non-flow away	2600	9,900	Calculated from seperated figures of processing and clean-up wastes.
14	Newmerow, N.L.	in general	-	3260	12,400	Average values

N.B.: Figures in this table are either taken from the literature as such or calculated to fit this table.

From Table III.3 we notice that the value of 8330 liters per 1000 birds presently employed, Shuman's poultry processing plant should be modified in accordance with current practices. It is noticed that values range from 9900 liters per 1000 birds to 17,000 liters per 1000 birds for non-flow-away poultry processing plant wastes.

Hence, it is assumed that water consumption in poultry processing should be increased to give 10,000 liters per 1000 birds, a value that corresponds to Boltons[7] Plant A in Table III.2. The reason for this is that this plant has a non-flow-away system and the feathers are scooped away from the floor manually and placed into containers. However an enclosed bleeding room is provided. This plant is very similar to Shuman's poultry processing plant at Beit Miri with the exception of the provision of a separate bleeding area.

Effect of Increase of water use:

The increase of water use, and hence volume of waste of waste water to 10,000 liters per day amounting to about 12% means that the waste waters would be diluted and concentration of the waste constituents given in Chapter II have to be reduced by a factor of 12%.

(iii) Working Hours: The number of working hours in the future will remain at the present five hours per day, 6 days a week. The exact hourly variation of flow cannot be estimated. Instead, a rough hourly estimate is given in the following hydrograph showing the estimated daily variation of flow to the proposed treatment plant from Shuman's poultry processing slaughterhouse.

Calculation of hydrograph values: It has been established that 3000 birds are to be processed using 10,000 litres per 1000 birds, hence a total of 30,000 litres of liquid wastes is expected to entrer the proposed treatment plant, the working hours are to be maintained at 5 hours, usually between 8:00 a.m. to 1:00 p.m. the flow beyond the working hours is nit since the slaughter-house is closed down when the processing is over.

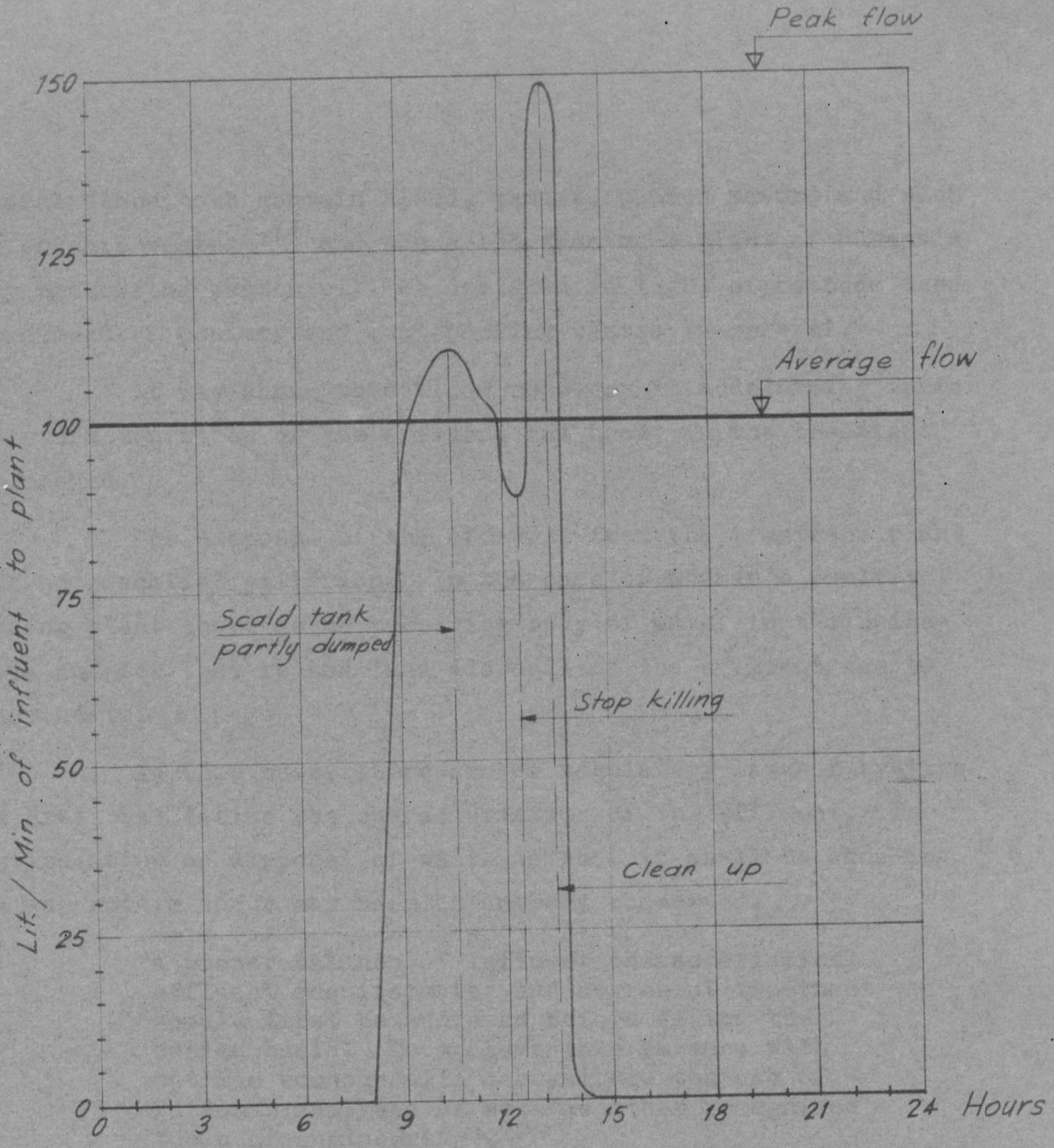
Average flow during working hours: The average flow per minute during working hours is then $\frac{30,000}{5 \times 60} = 100$ liters.

The average flow beyond the working hours is assumed to be zero, since no body stays at the slaughter-house beyond the working hours which eliminates the domestic use of water in the plant.

C. CURRENT TREATMENT METHODS OF POULTRY PROCESSING

General.

Poultry wastes are very similar to meat packing wastes



Peak flow at 150 litres per min. = 9.0 $m^3/hr.$ = 2.5 lps.

Average flow at 100 litres per min. = 6.0 $m^3/hr.$ = 1.66 lps.

ESTIMATED HYDROGRAPH OF FLOW OF WASTE WATER FROM EXPANDED SHUMAN PLANT.

Figure III.2

in general since both contain blood, manure, paunch manure and such highly organic wastes[7,14] and hence the treatment plant of Shuman's poultry processing wastes will be designed in light of methods used for treatment of poultry and meat-packing wastes in general.

It was shown that blood recovery is a determing factor in the characteristics of the effluent and hence in the treatment extent needed.

The disposal of the effluent from the treatment plant is also an essential criterion. In the case of Shuman's poultry processing plant there is no receiving body of water in the neighborbood; and for that reason land disposal of the effluent has to be resorted to.

In this case, there are no regulatory laws or by-laws in the area that define the characteristics of the effluent. The only stipulation on disposal of waste is that it shall be done in such a way not to incur any harm on anybody concerned.

> "A proper balance of influent characteristics, effluent requirements, and degree of treatment should first be achieved before fixing the design basis. To achieve this balance with optimum economy will necessitate the use of rational analyses as well as other recognized tools of engineering".[20]

As in the case of domestic sewage, there has been some controversy on the best methods of treatment of poultry wastes. Almost all kinds of physical, chemical and biological methods were used for the treatment of poultry processing wastes. The most commonly used will be discussed with special attention drawn to matters having a bearing on the proposal of waste treatment of Shuman's poultry processing plant.

1. Primary Treatment.

(i) <u>Screening</u>: It is an established fact that pre-treatment by screening is needed for the treatment of liquid poultry processing wastes.[3,5,7,14,19,21] Screens should preceed all forms of waste treatment providing for the removal of the coarser settleable, floating, and suspended solids.

Screens used for treatment of poultry wastes may be rotary, stationary, vibrating, or centrifuge type.[3,7] Various sizes of openings were used that vary from 0.0025 inch (200 mesh) to 0.5 inch.[20]

In the larger flow-away plants the poultry processing wastes are reported to be pretreated by mechanical rotary or vibrating 20-mesh.[3,7] The Shuman's poultry processing plant was explained to employ the non-flow away system and hence the use of the rotary type screens is dismissed as unwarranted because of comparatively low waste water production. In any case, some difficulties were reported in the case of rotary screens employed for feather screening.[7] The major difficulty was that of matting but this has been reduced by the use of water jets on the screens.

There is apparantly very little information on the performance of various screen sizes.[3,7] 20 mesh screens have been employed in many installations; while on arrangment of a trap with two or more one quarter to one half inch-mesh screen, mounted vertically and in a series following the mechanical screens were also reported to be a sucessful arrangement.[3,7] This latter measure of the trap and the screens in series was intended as a safety measure designed to collect spills and over-flow from the screens that would otherwise reach the treatment plant.[7]

One successful method of screening was employed in Georgia Sewage Plant for poultry wastes where the screen was a link belt drum screen covered with stainless steel cloth with six openings per inch.[22] The screenings are removed by means of a flight conveyor with metal shoes protected with rubber to prevent wear.[22]

A substantial portion of the BOD and suspended solids loads, in the form of flesh trimmings, bits feathers, is expected to be removed by screening.[8] The exact efficiency of such screens is not well defined, but should be approximated to about 10% removal of suspended matter.[5]

Since screening is such an essential part of treatment of poultry processing wastes it will be proposed as the first step in the treatment of the wastes from the Shuman's plant.

(ii) Grease Removal: Poultry processing wastes discharge an appreciable quantity of grease which is reported to be about 1.3 lbs of grease per 1000 birds.[14] The grease problem resulting from the discharge of this appreciable quantity of grease by poultry processing plants may become critical where large numbers of birds are processed.[3]

However, it is established that where primary facilities are available grease may be adequately removed together with other floating materials by the use of skimming devices in primary sedimentation tank.[21]

Sedimentation basins will not be adopted in the proposed design accordance with present practice in most of the treatment plants of poultry processing wastes.[3] However, whenever sedimentation basins are provided, grease traps are usually employed; but these are often a source of operational trouble. They are not particularly needed except when a large number of birds are processed. This operational trouble is explained to be due to the interference of feathers and trimmings in the operation of grease tanks.

Air flotation has been employed for the removal of grease and suspended solids but this is practicable when the floating material may be intended for yield of by-products.[3] Since the number of birds processed per day in Shuman's plant is relatively small, no grease traps are warranted.

(iii) Sedimentation: Most poultry processing treatment plants do not have primary treatment.[3] However, when poultry processing wastes or other similar packing house wastes are treated with municipal sewage sedimentation tanks are widely used.[5,19,23] Detention periods of 1.5 hours,[21] were employed in certain instances, while 2 to 4 hours of detention were employed in other plants.[19]

The efficiency of the reduction of sedimentation tanks in poultry wastes is reported to be as low as 17 percent BOD removal and 30 percent suspended solids removal.[3] Comparatively, an efficiency of 30 to 50 percent removal of BOD and 30 - 70 percent removal of total suspended solids is reported generally for sedimentation tanks employed normally for sewage treatment.[5] These values show that sedimentation basins employed for the treatment of poultry wastes have a low order of efficiency.

One example of the use of sedimentation basins for primary treatment of poultry wastes is found in a plant in Broadway Virginia where the total wastes produced by processing about 100,000 chickens per day are diverted to a sedimentation basins after inplant screening and recovery.[17] The sedimentation unit is 60 ft. long and 15 ft. wide and provides a detension period of 1.5 hours.[17]

The most important problem associated with sedimentation basins is that of sludge and scum disposal. Sludge and scum from primary settling units are usually handled, in the treatment of poultry processing wastes in one of the following ways:[3,4]

a) Digestion in separate sludge digestion tanks.

b) Lagooning.

c) Burial without digestion.

d) Drying with or without chemical conditioning.

Each of these methods of sludge treatment has its own inherent problems.

Mainly due to the fact that sedimentation basins were not efficiently used in treatment of liquid wastes from poultry processing plants and due to the problems involved in the sludge and scum produced from these tanks, no settling basins are proposed for Shuman's plant.

The following discussion on the treatment and disposal of sludge and scum from settling basins, is given to ensure a comlete presentation.

TREATMENT AND DISPOSAL OF SLUDGE:

a) Digestion tanks.

Scum and sludge produced in settling basins create the most difficult portion of the disposal problem mainly because their polluting strengths per unit of weight are greater than those of the liquid effluent from the treatment process that produced them.[19]

Separate Sludge Digestion: Space economy is better with separate digestion, and the operational problem is much more controlled by operators in separate digestion than in a combination unit, an example of which is the Imhoff tank.

One of the problems connected with the digestors is the need of agitation for better digestion.[5] The agitation makes it difficult or even impossible to withdraw the supernatent and sludge separately.[5] The other disadvantage of agitation is the cost.[5] The other problems include exacting control of temperature and pH. In general at low temperatures of 50° to 70°F reaction is very slow and gas production is limited and the gas is odorous, acids are formed, and there are some difficulties from foaming and poor separation of sludge and supernatent.[5] The optimal temperature range at which most digestors are operated is 80° to 95°F under the influence of mesophilic micro-organisms. The ambient temperature in the location of Shuman's poultry processing plant in Beit Miri is well below 50°F most of the winter season, and hence the reaction in digestion would be expected to be extremely slow if there is a reaction at all. Temperatures below freezing point have been registered in Shuman's records around 30 days a year. External heating would be necessary most of the winter and part of the spring; and the control of the heat exchanger is a delicate matter,[19] that could be avoided by the choice of other treatment methods.

A brief estimate of the quantity of sludge produced by the possible use of sedimentation basins is presented; although sedimentation basins are not proposed for treatment for the Shuman's plant.

Quantity of Sludge:[19] It was shown that the average suspended solids per 1000 chickens are 18.4 lbs. considering a decrease in this value of 10% due to screening, the suspended solids passing to the plant are about 16.6 lbs per 1000 chickens. Hence the Shuman's plant will produce about 50 lbs of suspended solids per day.

It was also shown that the average settleable solids are 7 mL/L. This is equivalent to a screened value of 0.9 x 7 = 6.3 mL/L. Since the plant would use 10,000 litres per 1000 chickens, as explained under volume of waste water produced, the settleable solids produced per day are approximately $6.3 \times \frac{30,000}{1000} = 189$ liters $= \frac{189}{3.78 \times 8.34} = 6.01$ lbs. Assuming settling would reduce the suspended solids by 50 per cent,[5] and 90 per cent of settleable solids: Quantity of sludge from suspended solids = 0.5 x 50 = 25 lbs per day and quantity of sludge from settleable solids = 0.9 x 6.01 = 5.4 lbs per day. Total quantity of sludge per day = 25 + 5.4 = 30.4 lbs. The wet sludge usually consist of 95 % moisture.[15]

Hence the pounds of wet sludge produced daily in the tank $= \frac{100}{5} \times 30.4 = 608$ lbs. At 63 lbs per cu.ft. the volume of wet sludge produced daily is $\frac{608}{63} = 9.65$ cu.ft. Considering an open digestion tank with a detention period of three months the required volume is 30 x 9.65 = 289.5 cu.ft.

The pH of 7.0 of a sludge digestor is usually an optimum pH and generally the pH should not be allowed to fall below 6.5.[19] Since the pH of 6.0 has been recorded for the poultry wastes it is expected that the pH of the digestor will be too low for efficient performance.

In addition, the cost of properly constructed digestion tanks is rather high and the operating control necessary to prevent the creation of odours or other nuisances is delicate.[19] Another disadvantage of the digestion tank is the feeding or dosing of the tank. The greatest amount of organic matter flowing to the sewer should be uniform and continuous, the volume fed daily being one thirtieth of a temperature controlled digestion tank.[19]

The solids content in the tank should not be permitted to exceed 15 per cent, and the volatile acid content should not exceed about 2000 ppm.[19] One last factor in the consideration of digestion tanks for treatment of sludge of poultry settled wastes is the fact that even with most effective screening at the processing plant some pin feathers reach the settling tank, and possibly the digestor. These feathers will accumulate especially in the scum mat and produce an operational trouble since feathers are not readily digested.[3]

b) Lagooning of Sludge.

Lagooning of sludge is looked upon by some authorities as an inadequate, in complete, and unsatisfactory method of sludge disposal. The main disadvantages are odours and land requirement.

The volume required for lagoons treating sludge from sedimentation basins is estimated in comparison with established figures of lagoon requirement for treatment of domestic sewage.

It is established that 0.6 cu.ft. of lagoon area are required per capita for sludge from domestic sewage. Since the major criterion for the design of the lagoon is the BOD loading, a rough estimate of the size of the lagoon can be found by findging the population equivalent of the waste-waters in terms of BOD. This ensures similar BOD loading in both cases.

The population equivalent based on 0.17 lbs of BOD per capita is 440 people and hence the volume required is 440 x 0.6= 264.0 cu.ft/day the depth of these lagoons vary between 12 and 18 inches, say 15 inches.

Hence the required area is $\frac{264}{1.5} = 166$ sq.ft./day.

Assuming a detention period, for digestion, of three months then the required area is:

166 x 90 = 14,940 sq.ft, which is about 1500 sq.m.

c,d) Burial without digestion and drying of undigested sludge.

The method of land burial or drying of undigested sludge requires large tracts of land, and indications are that the sludge may remain moist and may produce offensive odours for years and the land may be rendered permenantly unfit for further sludge burial.[19] In addition, it may cause pollution of underground water flows. At present there are no wells in the vicinity of Shuman's plant, but underground water pollution might cause a hazard to a downhill small spring that flows sometimes in the winter season, although this is not definite.

All the foregoing methods of treatment and disposal of sludge from sedimentation basins are avoided by the dismisal of these basins. In the light of the above, no primary treatment is proposed.

2. Comparative Study of Treatment Methods.

The current methods of treatment in connection with poultry processing wastes employ whenever practicable, a combined treatment of these wastes with municipal sewage.[4,7,23] Since municipal sewage treatment is not available in the area at all, the only method possible is that of treating the poultry processing waste alone.

Almost all familiar methods of sewage, treatment were used for the treatment of poultry wastes.[4,5] The most important of which are the following:[3,4,7,23]

(a) Trickling filter and activated sludge, (b) Extended Aeration or total oxidation, (c) Land application, (d) Sand filtration, (e) Chemical treatment and Chlorination, (f) Lagooning, (g) Anaerobic digestion of whole waste.

The various poultry processing plants in the world have employed one or more of the above mentioned treatment methods. Broadly speaking, any one of these treatments can be possible with various degrees of efficiency. However, a comparison among these treatment methods is necessary to facilitate the choice of one treatment method for Shuman's plant the choice being as economical, efficient and practical as possible.

A comparative study should be mainly done in light of the following criteria:

Effectiveness in treatment, cost initial and operating, operational skill required, extent of use (examples), basic design criteria (topography, area, volume of waste) efficiency in reduction of BOD and suspended solids loads.

Figures given in the literature for these points are not consistent. This is expected since the treatment of poultry processing and packing house wastes is rather a recent development in sanitary engineering.

The proposed treatment for the Shuman's poultry processing plant is to be done as a conclusion to this comparative study.

It is clear however, that such a proposal is only an optimum solution and not the only possible one.

a) Trickling filter and Activated Sludge.

The trickling filter and activated sludge process have been used for treatment of poultry wastes on a limited scale with good results. Filtration included low rate and high rate, as well as double filtration.[5] However, these bilogical processes did not recieve wide application in poultry processing wastes because of relatively high construction costs and exacting operational requirements.[3]

Screening, settling and equalization are fundamental operation for the proper functioning of the trickling filter and the activated sludge process.[3]

The treatment of poultry wastes with municipal sewage by trickling filters or activated sludge has been successfully operated.[3,5,7,19]

A major problem in the design of trickling filter and activated sludge process for the treatment of industrial wastes such as poultry processing is the fact that the daily operation is only for a few hours a day (5 hours in the case of Shuman's plant). In addition plants usually do not operate on weekends-four days in the U.S. and 6 days in Shuman's plant.[3] This intermittent operation with no flow for 19 hours a day will affect the microbial life and it will be necessary to provide recirculation in the biological units. The quantities of active microbial life could be appreciably destroyed because of the shortage of food in the non-operating hours.

In general, the efficiency of a trickling filter and the activated sludge process in removing BOD and suspended solids reach the order of 95 per cent.[3,5,19] A reasonable range of 75-95 percent of BOD removal and 90-95 percent suspended solid removal was also reported.[3]

One plant using trickling filters for treatment of poultry wastes with domestic sewage is the sewage plant of Gainsville, Georgia, and another is the sewage plant of Austin, Minnesota.[23] on the other hand the Chicago Sewage Plant[19] used the activated sludge process, with a 9-hour period of aeration and with 3½ to 5 cubic feet of diffused air per gallon of waste. Another test plant used trickling filters with a rate of 600,000 to 1000,000 gallons per acre per day.

> "There has been only one instance reported of a poultry plant using either trickling filtration or activated sludge for separate treatment of its wastes".[3]

b) ExtendedAeration or Total Oxidation.

Extended aeration is a popular modification of the activated sludge sewage treatment process that is particularly applicable to small installations.[3,24] This process utilizes a long term (24 to 30 hours) of aeration of sewage in the presence of activated sludge followed by settling of the mixture in a sedimentation basin.[3] The detention period of the subsequent sedimentation basin is usually 4 hours.[24] The supernatent is discharged and virtually the settled sludge is returned to the aerator. The process is often referred to as complete mixing, aerobic digestion, endogenous respiration, total oxidation complete mineralisation and other names.[3,6,24]

Extended aeration is gaining wide acceptance in the United States and in the year 1960, 1224 installations were reported of which 148 installations were for industrial use.[24]

The treatment efficiencies produced by the use of extended aeration of seven industries surveyed were as follows:[24]

TABLE II.4

Efficiency of treatment by extended aeration.

Design follow range gp d	Actual flow range % of design	5 day BOD removal % average.	Suspended solids removal average %
6900-100,00	31.2 - 131.5	88.1	62.7

Extended aeration is thought to be the most applicable type of treatment for the wastes for the Shuman's poultry processing plant since it primarily does not involve sedimentation and sludge digestion processes and since the waste has been reported to be successfully treated with the extended aeration as mentioned in proceeding examples.

The extended-aeration process has been developed by various manufacturers' plants each utilizing an operational system of its own. Following are some examples:[26,27,28]

TABLE III.5

Manufacturers extended aeration units.

Manufacturer	Country	Trade Name
Marlof	U.S.	Aerobic Digestion
Chicago Pump	U.S.	Rated Aeration
Yeomans	U.S.	Cavitator
Yeomans	U.S.	Hi-Cone
Smith & Loveless	US & U.K.	Oxigest
Infilce	U.S.	Vortair
Dorr-Oliver	U.S.	Dorr Mineralizator
Peters Co.	England	Defecamat
Drysdale	Scotland	Biomac
Matter & Platt	England	Wallace Two-Tier

Types of extended aeration units include, in addition to the above mentioned, complete mineralization by ditches as suggested by Pasveer.

Advantages of extended aeration process include small space requirements, low head loss through the plant, adaptability to a variety of topographic and climatic conditions, low field installation cost (in the United State), high treatment efficiencies with good operation, minimal odours and a minimal sludge problems.[29] A recent research done by Lowton et al.[25] showed that pH as low as 5.0 do not significantly affect the aerobic oxidation.

While the disadvantages include high power cost, periodic loss of suspended solids in the plant effluent, operational problems associated with sludge return from the settling tank, control of return sludge pumping rates, and pump clogging problems.[29]

One extended aeration plant was used for treatment of poultry processing wastes in Hiddenite, North Carolina.[3] The plant was desinged for the treatment of the processing wastes of 20,000 birds per day through it was producing only 19,000 birds per day. The treatment was reported to provide 90 percent BOD removal and 79 percent suspended solids removal.[3] The operational difficulty that was reported was the build up of feathers and other solids as a mat at the outlet of the aeration tank.

Each of these units employ extended aeration either mechanically or by the use of diffused air or systems employed both. Mechanical aeration methods include the Sheffield paddle, the Hartley aerator, the Imhoff submerged paddles combined with diffused air, jet aeration and the brush aerator.[19] Diffusors are either plates or tubes and are made of different materials.[20]

> "The major disadvantage of most porous diffusers is their progressive clogging and their need for periodical cleaning even when supplied with filtered air. Cleaning may not restore the diffusers to their original condition. Unless due allowance for probable increases in air pressure is made at the time blower equipment is selected, serious operating difficulties may be encountered."[20]

Modern designs of diffusers claim to have overcome these problems.

On the other hand, mechanical aerators have been installed to serve very small populations, and since 1955 mechanical aeration was seldom used for populations much in excess of 5000 people.[20]

Mechanical aerators of the brush or paddle type are easy to handle. For avoiding the possibility of problems associated with diffusers, and since mechanical aerators of the brush type are easy to handle in addition to the fact that such types have proven successful in smaller plants, such mechanical brush aerators will be proposed for the extended aeration plant selected for the treatment of waste waters from Shuman's plant.

A full description of the units of the extended aeration plant is presented in the proposal in Chapter IV.

Other treatment methods should first be compared as to their efficient applicability to the problem in question.

c) Land Applications.

Disposal of liquid wastes from food processing industries onto land area in rural locations is becoming a common practice whenever practical.[5] The practicability of disposal by land application depends on the nature and character of the soil, location and topography of the land, climate conditions, ground water table level and the cover crop in regard to absorption and transpiration capacities.[3] "Many packing-house industries have found this technique more economical and even generally more satisfactory than other processes."[5]

Land disposal can be used for two reasons: to dispose of the waste completely by percolation into the soil or for irrigational purposes.[1,5,14]

Land disposal of slaughter house wastes is usually done in one of the following methods:

Spray Irrigation:

This is gaining favour in USA especially for treatment of poultry wastes in semi-isolated areas.

The characteristics of the waste is naturally of major importance to the type of vegetation intended for the irrigation area.[5]

Where sufficient land is available spray irrigation is advantageous because of low capital costs of treatment equipment and simplicity of operation and maintenance.

The basic emperical relationship for the area required for spray irrigation is the following: "55 acres of land for 50,000 birds slaughtered weekly, although more acreage is desirable."[3]

The Shuman's poultry processing plant will slaughter 3000 birds per day x 6 =18,000 birds per week and hence:

$$55 \times \frac{18,000}{50,000} = 19.8 \text{ acres}$$

$$19.8 \text{ acres} = \frac{19.8 \times 43,200}{3.28 \times 3.28} = 80,000 \text{ m}^2$$

It is very obvious that such an area of land is not available for this usage.

One example of a poultry slaughter house using spray irrigation sprayed 20,000 gallons per day after screening and equalization.[3] Entire equipment costs amounted to $ 1800, and operational and maintenance costs were about $ 2000 annually.[3]

Ridge and Furrow.

The untreated liquid waste can also be distributed over land areas more cheaply by a series of feeder and contour ditches than by spray irrigation.[5]

Contour ditches are usually V-shaped, approximately 16 inches deep and located 6 to 10 ft. apart.

The most major problems in ridge and furrow system is that these systems may develop odours and insect infections because of accumulation of solids within the furrows.[3] One other problem is that of heavy rainfal is the case in Beit Miri, where the process might be interrupted.[5]

The ridge and furrow system is not suitable for steep country (like the Shuman's plant) and is normally applied in relatively flat areas.

An example of a ridge and furrow system was employed for the treatment of poultry processing wastes of a chichen plant in Wisconsin.[3] The ridge and furrow system covered an area of 1.05 acres to treat 15,000 gallons of waste water per day, 4 days a week, and the final effluent was very clear.

Flood Irrigation.

In this case the land is flooded with the waste water which percolates through the soil and is collected, if necessary in underdrains. The mechanical and biological powers of the soil are used in this particular treatment.

One example of poultry slaughter house using the flood irrigation method is found in Arkinsas U.S.A. where this plant utilizes an average of 18,000 gallons per day of screened and settled plant effluent. The equipment costs were approximately $ 1000 and maintenance cost was about $ 2500 per year. Little odour was reported.[3]

d) Sand Filtration.

Sand filtration has proved unsatisfactory for treatment of poultry processing wastes, because the sand filters clogged rapidly.[3] In addition the constructions costs were high, and its use is hence not recommended.

e) Chemical Treatment and Chlorination.

There is some controversy in the literature regarding the use of chemical treatment by coagulation for the treatment of poultry processing wastes. Experimentation in pilot plants and in the laboratory is necessary for determining the effectiveness of any particular chemical treatment.[15]

It was reported that chemical treatment was investigated for wastes from a flow away system in a plant processing eviscerated pack chickens in North Carolina.[3] ~~In~~ Combinations with lime, alum and ferric chloride were used separately as coagulants on composite samples of wastes. Analytic determinations taken on the supernatant, after 30 to 60 minutes of settling indicated about 65 percent reduction of BOD and 60 percent reduction of suspended solid. It was stated that alum coagulation was more efficient, and that 650 pounds of alum and 150 pounds of lime would provide the above mentioned treatment for each one million gallons of poultry wastes.[3]

On the other hand Gurnham states that for meat-packing house wastes in general, the floc produced by alum is too light for good settling; hence the iron chemicals are more commonly used.[5] Lime was reported to be used alone but is not fully satisfactory;

and hence it is more used for pH adjustment in coagulation, with aluminium and iron salts.[8]

Zinc salts gave good results in the treatment of packing-house wastes but the expense encountered makes them beyond practical consideration.[19] "Ferric chloride and ferric sulfate are by far the most popular coagulants for this type of waste."[5] Furthermore, Babbit[19] states that if the packing house wastes are very strong and cannot be mixed with domestic sewage, chemical precipitation may be desirable.

On the basis of this diversity in optimum coagulant use and optimum dosage and to be able to choose properly the most feasible chemical treatment for Shuman's poultry processing plant, it was found that experimentation in the laboratory was essential. Fair and Geyer mention that in general experimentation in the laboratory and in pilot plants is necessary for optimal determinations.

<u>Chlorination</u>:

Liquid chlorine may be used successfully as a precipitant in the chemical treatment of meat-packing and poultry wastes.[19] About one to one and a half parts of chlorine are required for each part of total nitrogen, when the pH is adjusted to about 4.0 by the addition of some acid, usually sulfuric acid.[19]

Since the poultry processing waste from the Shuman's plant contains about 1520 mg/L of BOD and 210 mg/L of total nitrogen, the amount needed of chlorine is expected to be high because of the high organic nature of the waste-water.

In general chlorine dosage needed for such organic wastes is high. Gurnham[5] states that chlorination of liquid wastes offers some benefits but it has been abandoned because of high operating costs and toxicity of the sludge.

However chlorination in connection with treatment of poultry wastes was used more often as a final treatment of effluents or for pretreatment of the wastes. In the first case chlorine is applied with a contact time of 15 minutes to have a chlorine residual of about 0.2 - 1.0 mg/L, although a chlorine dosage to produce 2.0 mg/L has been suggested.[3]

Results of Laboratory tests on Chemical Treatment and Chlorination.

Coagulation Jar Test.

The coagulants used in the jar test were lime and alum in various combinations, ferric chloride and bleaching powder. The jar tests were done on settled liquid wastes from Shuman's poultry processing plant. The settling time was about 45 minutes in Imhoff cones and the samples were taken from the supernatants of the cones.

The efficiency of this chemical treatment was estimated by comparing the BOD of the waste water before and after the chemical treatment.

Table III.6 shows the results of the coagulation tests. The interpretation of the results of each test is given below:-

TABLE III.6

Results of Coagulation Jar Tests.

No.	Coagulant aid	Concentration in mg/L		pH		Colour	
				Before treatment	After adjusment	Before treatment	After treatment
1	FeCl$_3$	50		6.0	-	dark pink	same
2		100		6.0	-		same
3		200		6.0	-		a bit lighter
4		300		6.0	-		light pink
5		350		6.0	-		rather clear
6		400		6.0	-		clear
7		450		6.0	-		very clear
8	Chlorination with bleaching powder containing 25% strength	150		6.0	5.0	dark pink	light pink
9		255		6.0	4.8		clear
10		320		6.0	4.8		very clear
		Lime	Alum				
11	Lime & alum	200	80	6.0	7.0	dark pink	same
12		750	100	6.0	8.0		light pink
13		80	200	6.0	6.8		rather dark
14		480	200	6.0	9.5		clear
15		180	300	6.0	6.8		pink
16		380	300	6.0	7.5		light pink
17		580	400	6.0	8.0		very clear

In order to evaluate the reduction of organic strength due to coagulation, BOD tests were done on the supernatant of samples 7,10 and 17. The results are given in Table III.7.

TABLE III.7

BOD Tests of Supernatants

No.	$FeCl_3$ mg/L	Chlorine mg/L	Lime and Alum		BOD in mg/L		Color
			Lime mg/L	Alum mg/L	~~Before test~~	After test	After test
7	450	-	-	-	~~8.0~~	28.0	very clear
10	-	320	-	-	~~8.0~~	31.0	very clear
17	-	-	80	400	~~8.0~~	29.0	very clear

Interpretation:

Generally, the amounts of coagulant needed for proper chemical precipitation is high:

$FeCl_3$. A dose of 450 mg/L (sample No.7) means an amount of 450 x 30,000 = 13,500 gm. of $FeCl_3$ per day.

Bleaching Powder. A dose of 320 mg/L bleaching powder of 25% strength (sample No.10) means an amount of 320 x 30,000 = 9,600 gm. of bleaching powder per day.

Lime and Alum. A dose of 580 mg/L (sample No.17) of alum which gave the best results means 580 x 30 = 17,400 gm. and 400 x 30 = 12,000 gm of lime and alum per day simultaniously.

All these chemical requirements are high and the operating cost will eventually be high if such a treatment is to be used.

It is reported however that generally chemical treatment of poultry processing wastes is expensive and not too effective.[3]

f) Lagooning.

When poultry processing wastes are to be treated with domestic sewage, lagoons are very widely used; although lagooning is often used as a separate treatment of poultry processing waste alone, if conditions are favorable.[3] Taken as an example, the design criteria for lagoons treating combined poultry processing and domestic wastes in the United States(Arkansas, Missipi and Alabama) indicate 5-day-BOD loadings approaching 50 pounds per acre per day.[3]

Lagoons for treatment of liquid wastes are expected to provide 70 to 95 percent reduction in BOD if they are properly loaded and operated.

Screening is required before the wastes are discharged to the lagoons. Many treatment plants provide for settling tanks in addition to screening as a primary treatment before disposal of the waste in the lagoon. It was reported that screening and settling provided for 50% reduction of BOD in a plant in Indiana.[3] The pond loading in this plant was around 150 pounds BOD per acre per day. Since the loading was high, ammonium nitrate was added at a rate of 140 pounds per week in summer and 35 pounds per week in winter for additional supply of oxygen. The needed sodium nitrate usually containing about 56 per cent available oxygen cares for 20 per cent of the BOD.[19] The lagoon capacity of the pond is 300,000 gallons and its depth is 12 inches. The Indiana lagoon showed 81 per cent removal of BOD.[3]

On the other hand, it was reported by Anderson et at.[4] that the nutrients in poultry evisceration wastes are sufficiently high to warrant re-evaluating generally accepted lagoon design critiria toward an increased surface loading. They also reported a surface loading of about 214 lbs. per acre per day to appear feasible in high rate oxidation pounds with potential BOD reductions from 70 to 96 per cent. A reported depth of the lagoon of 18 inches resulted in satisfactory operation.

Budd et al.[17] report on another plant treating poultry processing wastes at Broadway, Virginia that processes 120,000 chickens per day. The plant utilizes screening and settling tanks as primary treatment. Following the sedimentations basis, there are lagoons in series. These lagoons are 150 ft square by four ft. deep and are designed to give a retention period of seven to ten days. The efficiencies achieved in this plant are given in Table III.8

TABLE III.8

Efficiency of treatment by lagooning in Boradway plant.

Raw Processing wastes	BOD	Suspended solids	Dissolved solids
Raw effluent	1047 ppm	312 ppm	673 ppm
Final effluent	275 ppm	26 ppm	470 ppm
Per cent efficiency	72	92	30

Lagoons in general require large tracts of land with convenient contours and create a possible problem of odour. In addition lagoons might become breeding places for mosquitoes and other insect pests.[3] The design of the lagoon also depends on climatelogical factors in as far as evaporation and oxygenation of the waste waters. The growth of weeds producing above the water surface should be controlled by the minimal depth because higher depths would prevent penetration of adequate sunlight and hence a deficiency of oxygenation by algeal growth. Another limiting factor is the possible formation of sludge banks.[19]

The Shuman's poultry processing plant would produce eventually after screening about 25.2 lbs of BOD per acre per day. Considering a loading of 100 lbs per acre per day taken as an average, a quarter of an acre of lagoon is needed per day.[3] Considering a detention period of 100 days, as in the case of the Broadway plant mentioned above, the Shuman's plant would require 2½ acres (10,000 sq.m.) of land.

Land in Shuman's plant is not available for such use, in addition to the fact that the steep contours of the land makes the possibility of lagooning inconvenient in any case.

g) Anaerobic Digestion of whole waste.

Anaerobic decomposition or digestion of whole wastes is a recent development in waste treatment that is finding application in the treatment of meat-packing effluents.[5] Anaerobic fermentation has proven successful in the disposal of such organic wastes.[19]

Gurnham[5] reported that in a pilot plant treating packing house wastes a reduction of 90-95 per cent was consistently obtained as a result of anaerobic digestion of whole wastes for a period of 24 hours. A temperature of 90 to 92°F was maintained by external heating through a heat exchanger. The process is in a pilot stage but the short 24 hour detention time has proved so favorable that the process will definetely be given a fulle-scale trial.[5] The Shuman's poultry processing plant producing 30,000 liters of waste water per day would require on the basis of 24 hours detention a capacity of 30 m^3 for the liquid waste. In addition to this, the volume needed for gas collection, based on an assumed value of 0.5 volumes of gas per volume of tank,[15] is $0.5 \times 30 = 15$ m^3. Total volume of tank $30 + 15 = 45$ m^3. For proper functioning such a tank will need external heating.

Most of the problems discussed under sludge digestion would be applicable to the anaerobic decomposition of whole wastes.

The efficiency involved in anaerobic digestion of whole wastes is reflected in the efficiency of the septic tank already in use at Shuman's plant as given in Table III.1, and which indicates a low order of efficiency.

The volume of the present septic tank is 3.0 x 2,0 x 3.0 = 18 m^3 and the present flow of waste water is 5 m^3/day, for 5 hours. Hence the detention period in the tank is 3-4 days. The low efficiency is atributed mainly to the absence of optimal temperature and pH conditions.

3. CONCLUSIONS

(1) Screens are inevitable in treatment of poultry processing wastes.

(2) Primary treatment is usually needed when poultry processing wastes are treated with municipal sewage; and is not present in separate treatement plants, since sludge digestion or any other sludge treatment and disposal method may create unnecessary problems. Sludge treatment by either the use of digestion tanks or lagoons and sludge disposal by burial have inherent problems that are avoided by not using sedimentation basins for primary treatment.

(3) Treatment of wastes by trickling filter is avoided mainly becuase the flow of waste is only for 5 hours a day and since the filter needs continuous recirculation to keep the flora of the microorganism living. Trickling filter is widely used when poultry processing wastes are treated with municipal sewage, which is not possible in the case of Shuman's plant.

(4) Treatment of wastes with an activated sludge process offers great operational and cost problems; and is usually not warranted except if poultry processing waste is treated with municipal sewage.

(5) Land application is not feasible mainly because of the non-availability of the needed land areas and because of its steep topography. In addition, land disposal of liquid wastes might cause odours and unsightly areas.

(6) Chemical treatment is not warranted mainly because of high operational cost and the fact that it has not been proved very effective as far as poultry wastes are concerned.

(7) Lagoons have proved successful in the treatment of poultry wastes but in the case of Shuman's plant the required areas and topography of the land in addition to problems of odour, insects, pests and chimatological factors render lagooning unfeasible.

(8) Anaerobic Digestion of Whole Wastes for a short period of 24 hours detention. Efficient functioning mainly requires optimal temperature and pH conditions and is still in its pilot stage.

(9) Extended Aeration, with its variety of types and units, seems to be the most reported sucessful treatment of poultry processing waste-waters from smaller industries. This process seems to offer the least number of plant problems in addition to its low initial cost. Extended aeration commonly includes all plants employing total oxidation, complete mineralization, endogeneous respiration and others. Small industrial wastes are increasinly treated by units employing the extended aeration principles of complete mineralization.

British and U.S. manufacturers have recently developed cheap and economical package units employing the principle of extended aeration. Many manufacturers report very high efficiencies in the treatment of highly organic wastes, although all these units claim very high efficiencies in the treatment of domestic sewage.

After careful consideration of all other alternatives, extended aeration is selected in principle to be the basis of the proposed treatment method for Shuman's plant. The specific extended aeration unit to be selected is proposed by comparing different manufacturer's plant units.

In conclusion, the proposed system comprises screening of waste, no primary treatment and a selected extended-aeration unit. The effluent of this unit shall be used for land irrigation and shall be disposed of on the land adjacent to the existing slaughter house.

CHAPTER FOUR

THEORATICAL CONSIDERATIONS OF EXTENDED AERATION UNITS.

General.

The foregoing comprehensive discussion on the current methods of treatment of poultry wastes, and all figures, reasons and conclusions given thereinto indicate that a system involving mainly screens and an extended aeration unit is the most economical and efficient system to use for the treatment of Shuman's poultry processing waste-waters, after consideration of the various limitation of the Shuman's plant.

Since the Shuman's plant is relatively small, power costs involved in the extended aeration system will be reasonable. Pump clogging problems will be avoided by the type of pump selected. All the elements of the extended aeration unit are selected to give the easiest operational system and the most economical one.

A more complete theoratical evaluation of the extended aeration process for treatment of wastes flows, that are in the order of those present at Shuman's poultry plant, is deemed necessary. This evaluation would support the discussion and conclusions presented under extended aeration in the preceeding chapter. The basic theory involved in the extended aeration modification of the activated sludge process is presented to promote such an evaluation.

A. BASIC THEORY

> "The basic need in design and operation of activated sludge systems or any bilogical waste treatment system is for a thorough understadning of the microbiology and biochemistry of the activated sludge process. Such fundamental knowledge would permit the engineer to base his design on sound biological principles and would eliminate the differences in design between the various systems."[30]

The extended aeration system simplifies the conventional activated sludge process by the elimination of the primary settling tank and the anaerobic sludge digestion unit. The construction is also simplified and the difficult problem of sludge handling is minimized by a reduction in the quantity of sludge accumulated for disposal.[3]

The theory of extended aeration, as a modified process of activated sludge, is discussed only in the light of the most recent theories on aerobic oxidation. The various theories pertaining to the plant design are discussed under the design of the respective units.

The conventional activated sludge process was developed with the understanding that oxidation will take place utilizing aerobic micro-organisms. This aerobic oxidation is sometimes referred to as wet combustion, in which quantities of carbon dioxide are produced as the main product.[30] Extended-aeration involves total oxidation of the waste. Total oxidation, by definition, is a process so designed that the biological sludge produced by synthesis is consumed by auto-oxidation.[37] To accomplish this oxidation, the aeration detention period must be increased. A part of the cellular is highly resistant to oxidation and results in an accumulation in the process.[32] Theoraticaly speaking, if no portion of the cellular material is not oxidiable, total oxidation should give zero accumulation of sludge.[30] In smaller installation, this excess sludge accumulation can be removed by tank trucks. In practice smaller installations can remove the excess sludge accumulation by tank trucks. This practice is especially important if plant effluent discharges into a receiving body of water.

Total oxidation is sometimes referred to as the assimilation of substrate by the activated sludge and the eventual conversion of the substrate to oxidized nitrogen compounds and carbon dioxide (and water) without any increase or decrease in the total weight of the activated sludge in the system.[33]

In a very recent article, Lawson[34] describes the mechanism of biochemical oxidation considering the food to micro-organism ratio, F/M. Lawson states that when a rich nutrient solution is seeded with bacteria - a lag phase is noted, after which the cells begin to multiply at a rapid rate. In such a case the food to M.O. ratio, (F/M) is high. This growth is geometric in progression and it is only limited by the speed at which the bacteria can reporoduce. As the available food supply is reduced so does the growth rate, and this is proportional to the available food per unit micro-organism. In other words, the F/M ratio has dropped. Further decrease of the F/M ratio brings a situation in which there is only just enough food to keep the bacteria alive, and growth and death rates are equal. Further reduction of the F/M ratio, brings about a state of autolysis in which the bacterial population reduces itself by self-digestion (endogenous respieration). At this point the F/M ratio remains constant. High F/M ratios use approximately 67 % of the ultimate BOD for synthesis and at low F/M ratios the largest amount of BOD is used for energy or respiration, since most of the BOD is oxidized for energy and produces few new cells.

Generally speaking, it is theorized that (a) organic matter is removed from solution by reaction with enzymes that bring about coagulation (b) organic matter is oxidized; (c) bacteria cells are produced from organic matter removed, and (d) cell material is oxidized.[31]

In the cell material oxidation, there is definately an oxidation of protein materials with the production of nitrites and nitrates.[31]

1. BOD Removal and Stabilization[30]

There is an accepted difference between BOD removal and BOD stabilization. BOD stabilization occurs at some rate equal to or less than the rate of BOD removal; and it is the basic biological process that controls the extent of BOD removal. BOD removal is a step - wise function, adsorption on the activated sludge surface followed by absorption into the activated sludge. BOD removal has occured with adsorption while stabilization of BOD does not occur until it has been absorbed. Adsorption is a surface phenomenon depending upon the attraction of the organic matter for the activated sludge surfaces. Colloidal and suspended solids are readily attracted to the activated sludge while the soluble organic compounds are not easily adsorbed.

The activated sludge cannot adsorb organic matter on a continuous basis, unless the adsobed matter has been removed biologically by absorption into the living cells within the activated sludge and its subsequent metabolism. The key to the rate of removal of organic matter or its rate of stabilization lies in the rate of the metabolism and the factors controlling that rate.

2. Metabolism[30]

In extended aeration as well as in activated sludge, bacteria are the primary micro-organizms reponsible for metabolism. The bacteria metabolise organic matter for the reproduction of the species by a series of complex, interrelated biochemcical reactions. Such biochemical reactions have two functions, one to obtain energy and the other to obtain the building blocks for the synthesis of new cells. These two functions are interrelated quantitavely with a unit of protoplasm requiring the same energy whether the organic matter being metabolized is protein, fat or sugar. On an energy basis however, the same energy content in the organic matter will yield the same quantity of protoplasm regardless of its chemical nature, as long as adequate nutrients are available for complete protoplasm synthesis.

3. Synthesis.[30]

The synthesis of new cells is very important in extended aeration as well as in activated sludge, since it determines the continued activity of the sludge and the accumulation of excess sludge in the system. The initial metabolism of the organic matter results in its conversion to protoplasm, while in the activated sludge process it has been removed and stabilized when synthesis is complete. It was observed that there is a continuous turn over by protoplasmic materials in which the old components are metabolised for energy and new ones are synthesized to take their place. The process of internal metabolism of protoplasm has been defined as endogeneous metabolism. Hoover and Porges call the oxidation of the bacterial cell material "endogenous respieration" and state that it is analagous to the basal metabolism of man.[32] It is called respiration since the protoplasm is being metabolized for energy, as respiration is the energy phase of metabolism.[16]

The biological changes involved in microbic respiration are very complex.[16] All respiratory processes are dissimilitive in nature and such a tendency is toward the transformation of organic compounds into an inorganic state.[16] The term mineralization has been applied to such processes.

Fourney et al.[33] have done tests to ascertain the metabolism and the mechanics of total oxidation of a balanced organic substrate by means of activated sludge. Following are their conclusions:

(i) Total bio-oxidation does occur and an equilibrium of solids is established as an inherent condition.

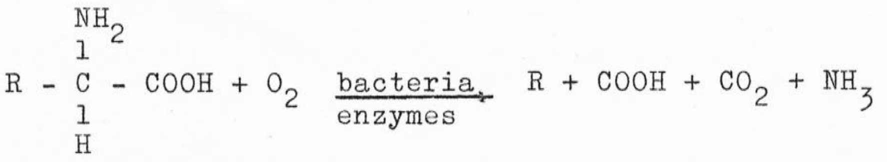
(ii) The equilibrium activated sludge requires 0.075 lbs of oxygen per day per pound of activated sludge at 75°F.

(iii) The equilibrium weight of activated sludge is 12 times the weight of influent organic matter at 75°F.

4. Elementrary Biochemical Equations.

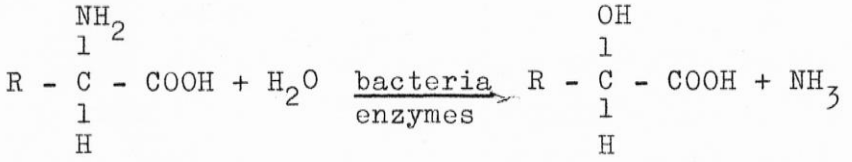
Since it was theorized that there occurs an oxidation of protein materials in the cell material oxidation, it is found necessary to include the most elementary of protein oxidation equations:- Hydrolysis of the proteins ultimately leads α - amino acids.[8]

Bacteria deaminize these amino acids under aerobic conditions to produce saturated acids with one less Carbon atom:



$$R - \underset{H}{\overset{NH_2}{C}} - COOH + O_2 \xrightarrow[enzymes]{bacteria} R + COOH + CO_2 + NH_3$$

or to produce hydroxy acids with the same number of carbon atoms:-[8]



$$R - \underset{H}{\overset{NH_2}{C}} - COOH + H_2O \xrightarrow[enzymes]{bacteria} R - \underset{H}{\overset{OH}{C}} - COOH + NH_3$$

Ammonia is oxidized first to nitrous and next to nitric acid in the respiratory processes of the nitrifying bacteria, that derive energy necessary in their life processes from such changes:-[16]

$$2\ NH_3 + 3O_2\ \underline{enzyme}\ 2\ HNO_2 + 2\ H_2O + 157.6\ cal.$$

$$2\ HNO_2 + O_2\ enzyme\ 2\ HNO_3 + 36.6\ cal.$$

These two steps taken together are referred to as nitrification.

B. BASIC CRITERIA OF EXTENDED-AERATION PLANTS.

General.

The design criteria of extended-aeration units vary with different practices and manufacturers design procedures, but the basic criteria for the different practices fall within reasonable limits of each other.

1. Basic Design Data (Practice in the United States).

(i) Screening: Comminuting devices are only required for bigger installations. Bar screens are required when comminuting devices are not installed.[24,35,36]

(ii) Duplicate Units: For plants to treat 40,000 gallons or more daily, at least two aeration tanks and two settling tanks are required.[35,36]

(iii) Aeration Tank: 24 hour-detention period at average daily sewage flow (not including recirculation)[35.36] Others[37] specify about 12.5 pounds of BOD per 1000 cu.ft. of aeration volume.

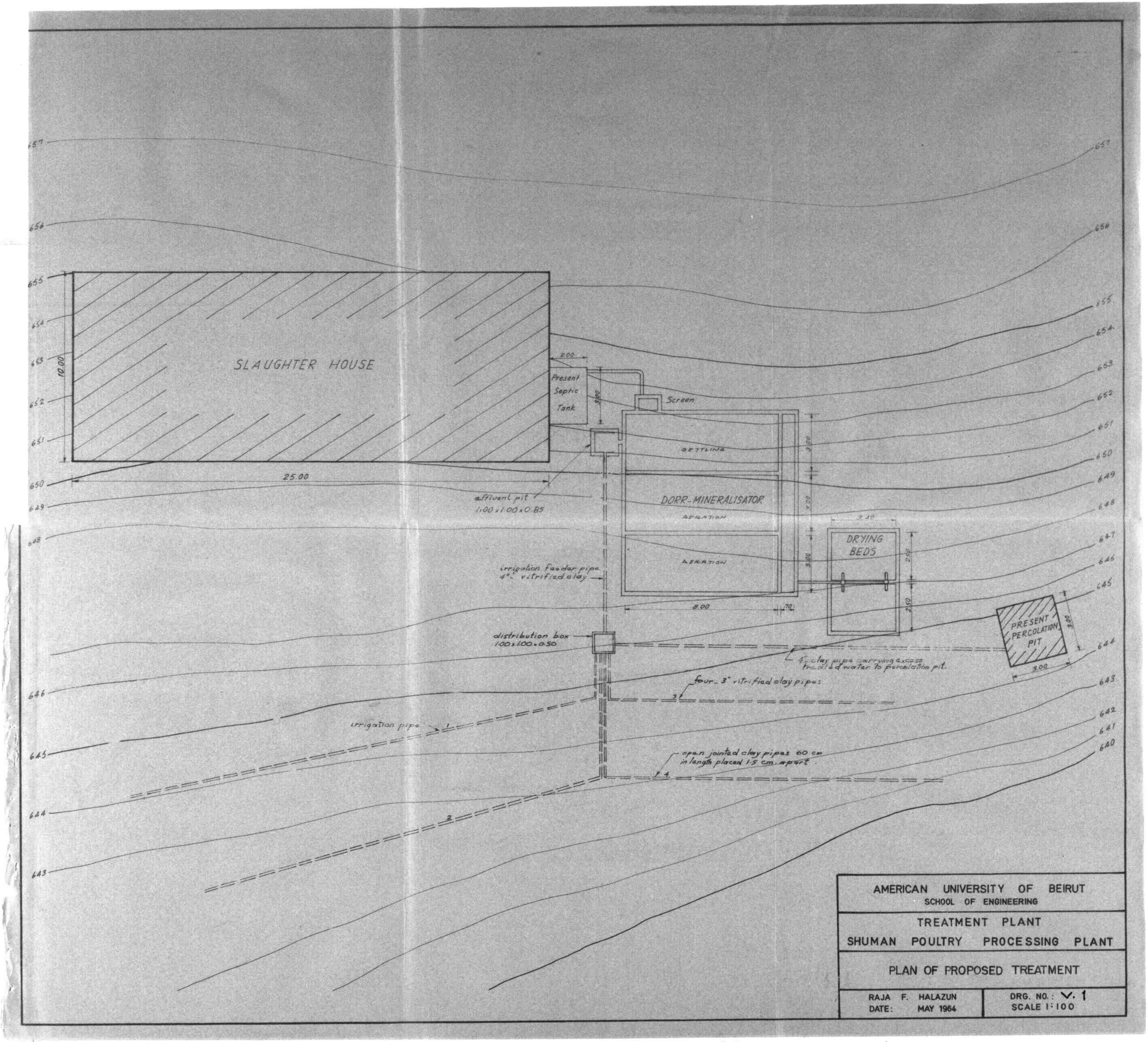
For smaller plants Dorr-Oliver requires about 1.25-days detention.[28]

Haseltine,[38] in a recent paper accepts the criterion of 24 hours detention as an absolute minimum and states that the solids to BOD input is a more important criterion. For extended aeration plants Haseltine recommends that the plant should carry 10 pounds of solids per pound of daily BOD input and indicates that with such an inventory there will be little build-up excess sludge. If this is the case Haseltine states that the build-up of bilogical cells due to synthesis of the incoming organic matter would be approximately equal to the destruction of the biological cells due to endogenous respiration.

(iv) Settling Tanks: 4 hour detention period for average flow (not including recirculation). For the tanks with hopper bottoms the upper third of the hopper may be considered as effective settling capacity.[33,36]

Haseltine[38] states that loading rates shall not exceed 800 gallons per square foot per day when based on average sewage flow alone, nor 1200 gallons per square foot per day when based on that sewage flow plus the nominal rate of return sludge as set in table under (e) below. Hasetline also states that multiple units capable of independant operation are desirable and shall be provided in all plants where the total tank volume requiremant for final setling exceeds 2500 cu.ft.

(v) Rate of Recirculation: At least 1 to 1 based on average design rate of sludge return as a percentage of the average design rate of sewage flow. This percentages varies with suspended solids content of mixed liquor as shown in Table IV.1.



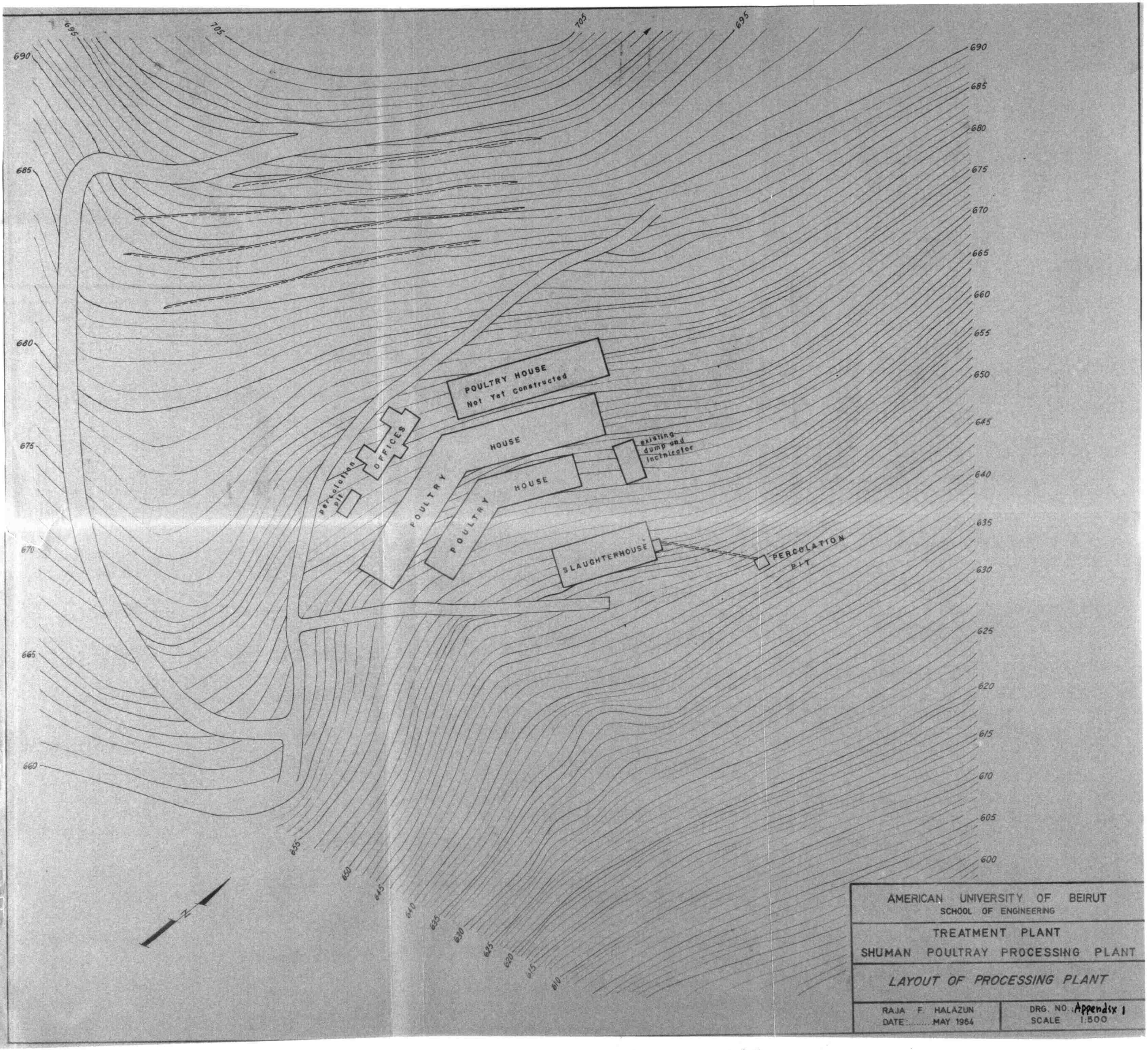
AMERICAN UNIVERSITY OF BEIRUT
SCHOOL OF ENGINEERING

TREATMENT PLANT
SHUMAN POULTRY PROCESSING PLANT

PLAN OF PROPOSED TREATMENT

RAJA F. HALAZUN
DATE: MAY 1964

DRG. NO.: V. 1
SCALE 1:100



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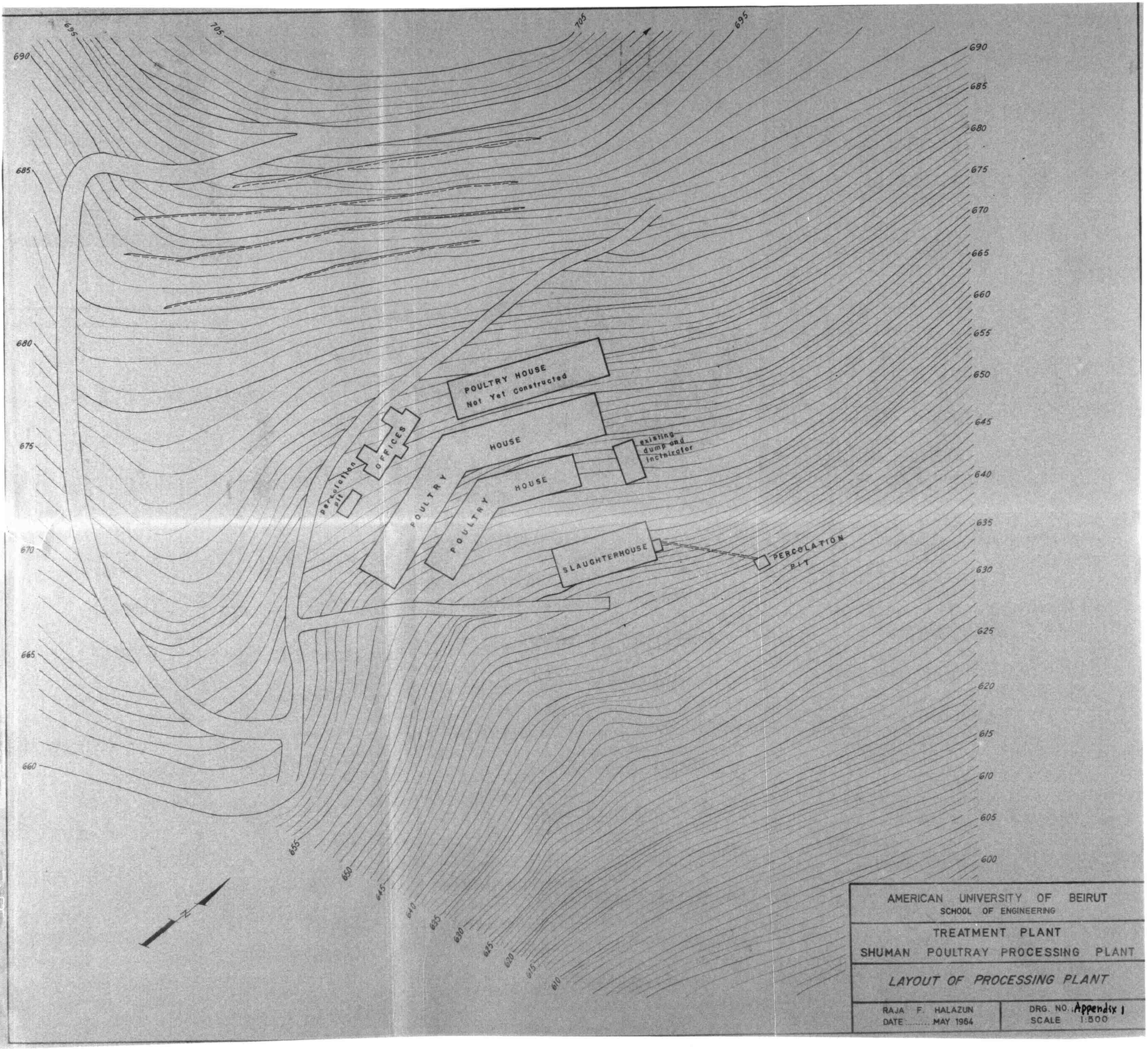
TREATMENT PLANT
SHUMAN POULTRAY PROCESSING PLANT

LAYOUT OF PROCESSING PLANT

RAJA F. HALAZUN
DATE: MAY 1964

DRG. NO.: Appendix 1
SCALE 1:500



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TREATMENT PLANT
SHUMAN POULTRAY PROCESSING PLANT

LAYOUT OF PROCESSING PLANT

RAJA F. HALAZUN
DATE .... MAY 1964

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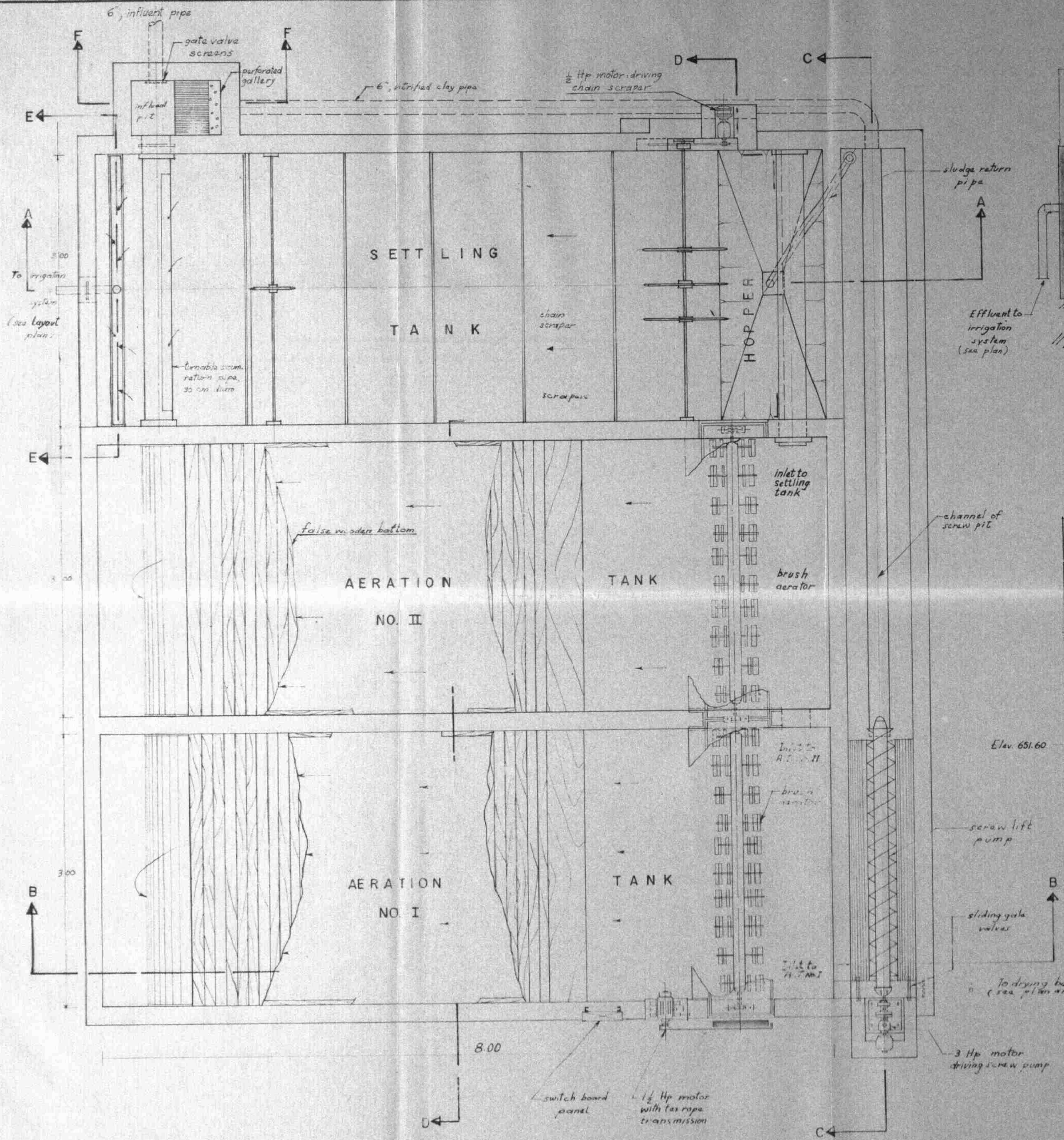
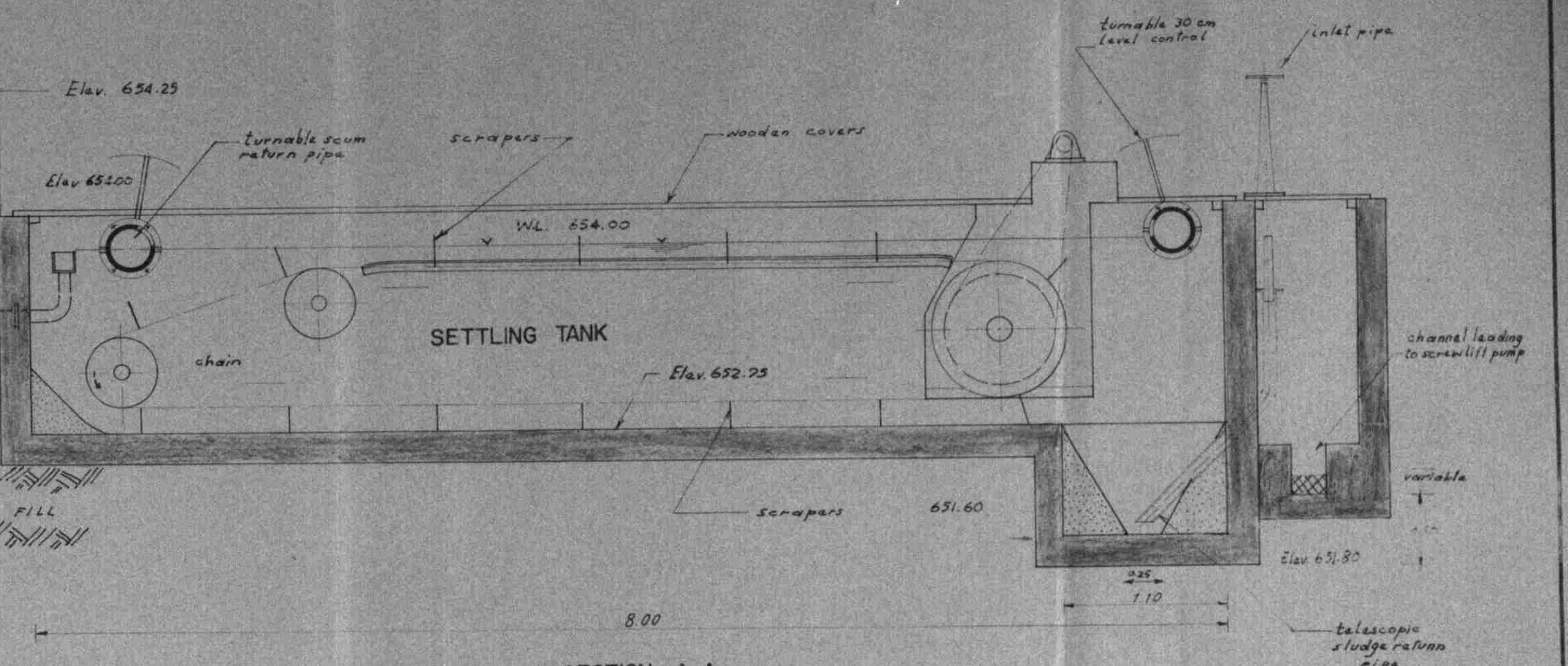
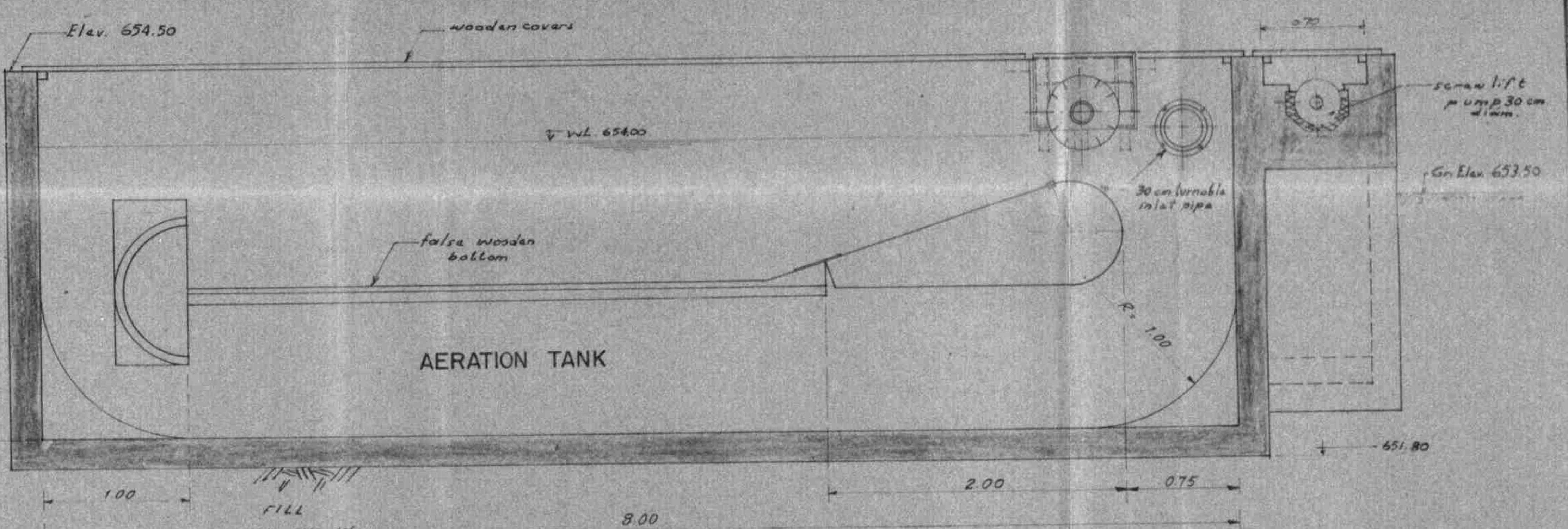


PLAN



SECTION A-A



SECTION B-B

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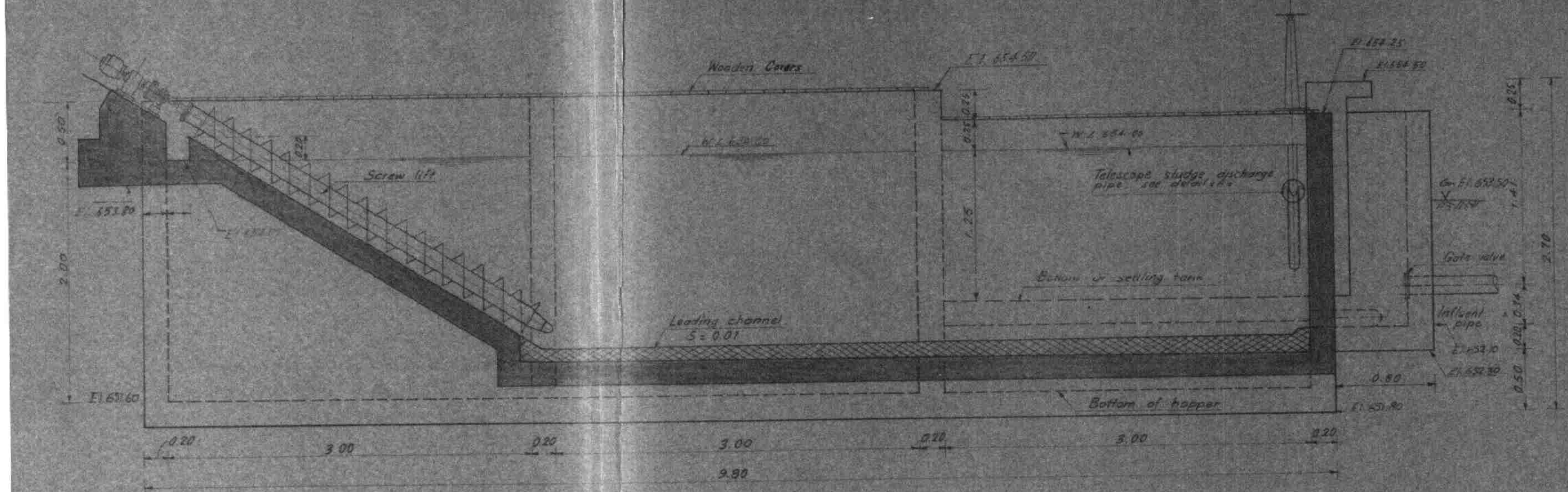
TREATMENT PLANT
SHUMAN POULTRAY PROCESSING PLANT

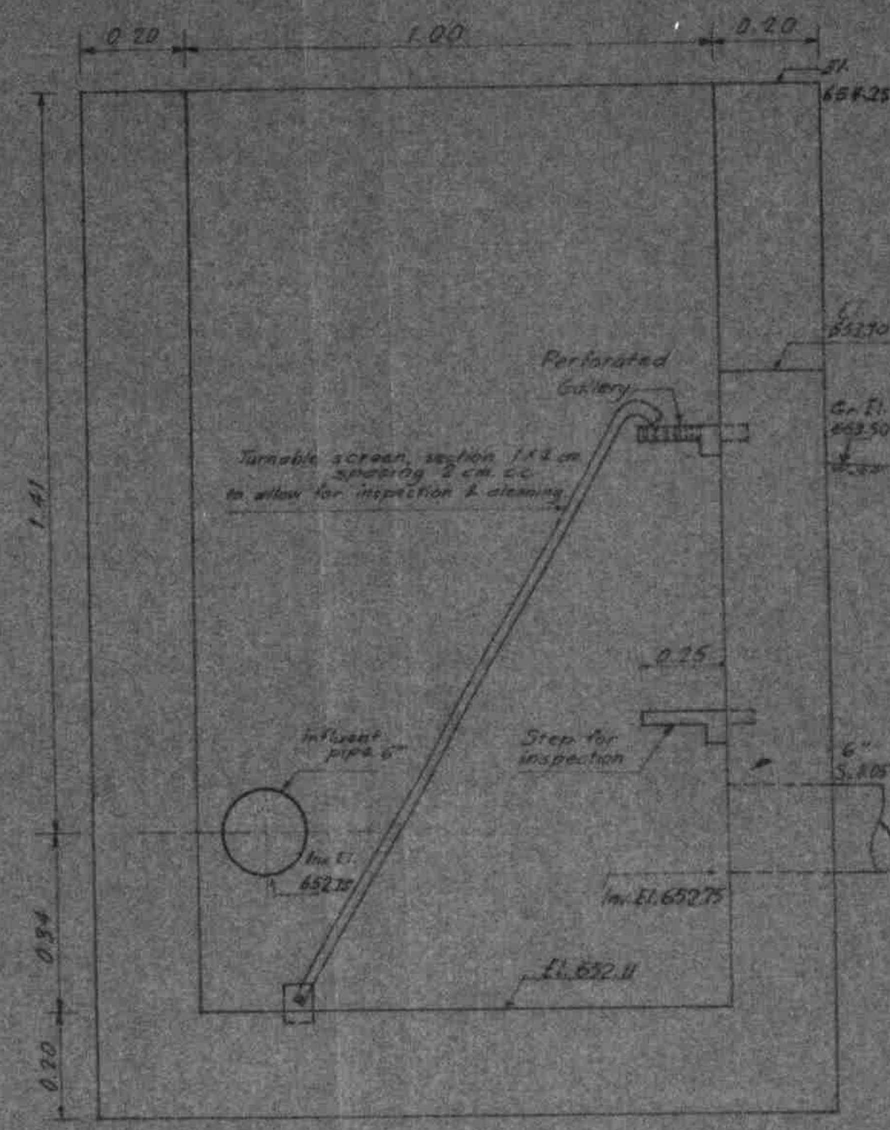
PLAN AND SECTION OF
DORR-MINERALISATOR

RAJA F. HALAZUN
DATE:........MAY 1964

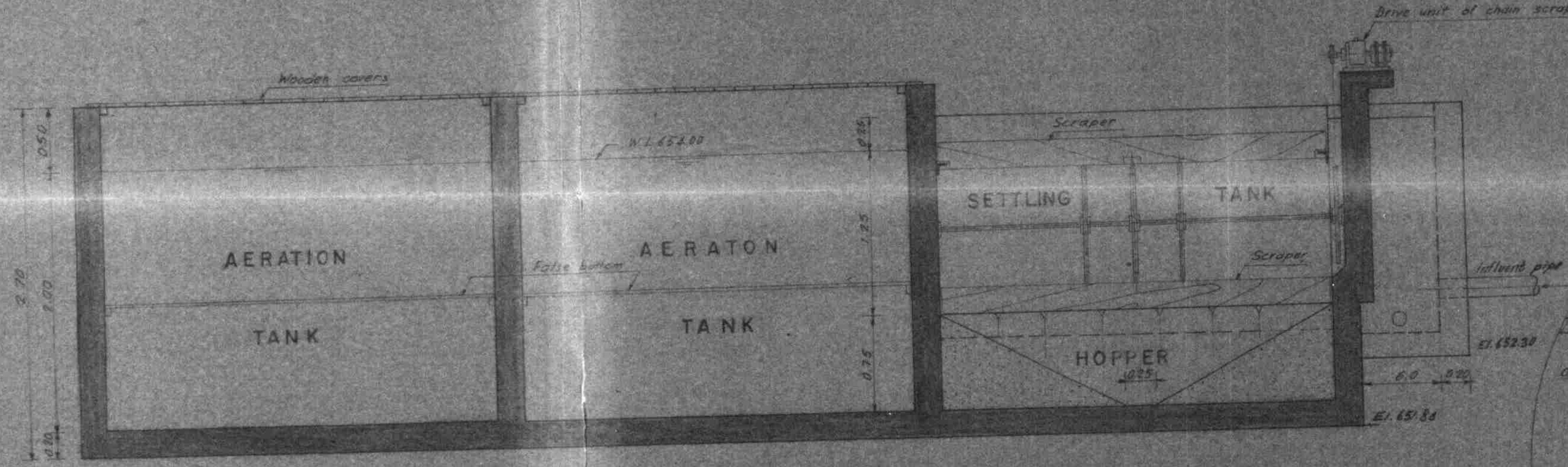
DRG. NO.: V.2
SCALE 1:25



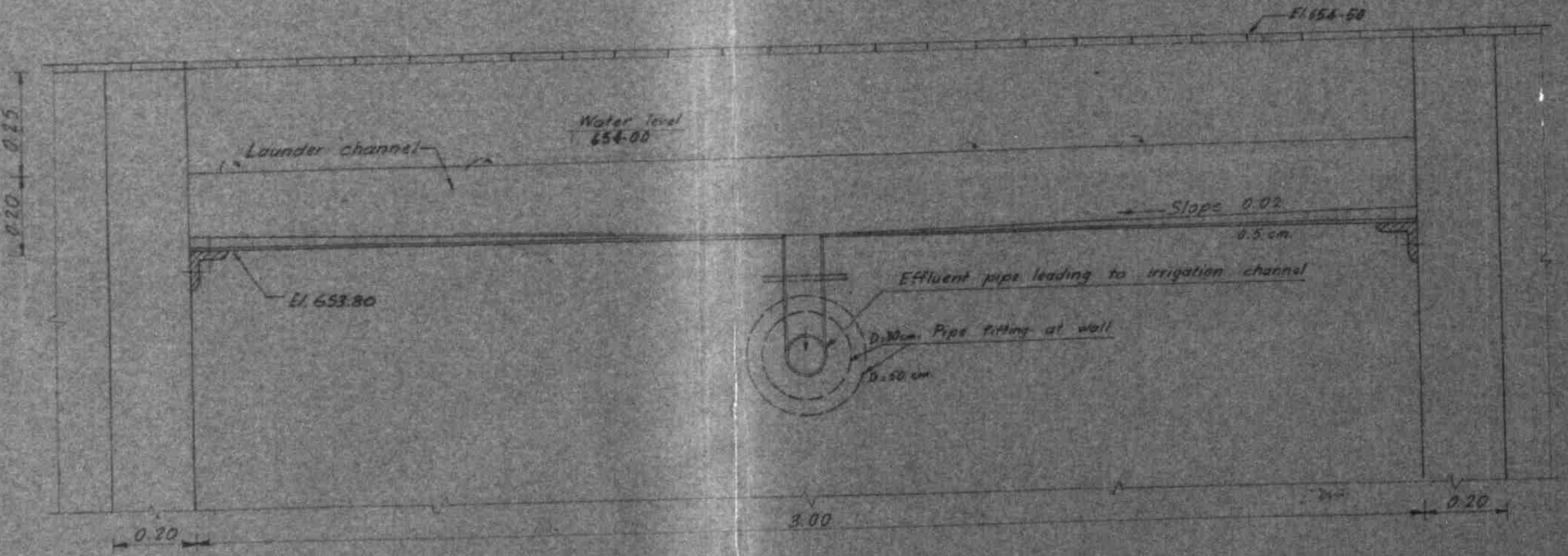
SECTION C-C
Scale 1:25



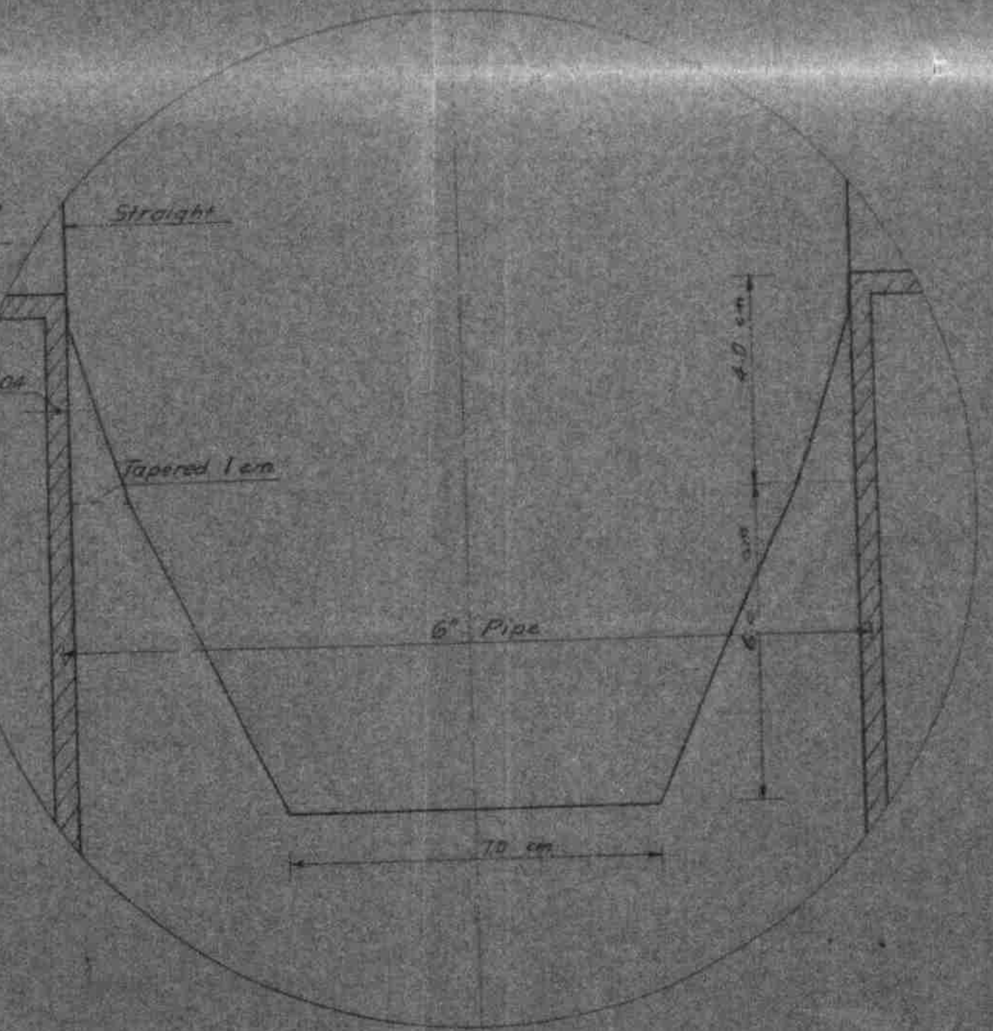
SECTION F-F
Scale 1:10



SECTION D-D



SECTION E-E
Scale 1:25



DETAIL (A) Scale 1:10

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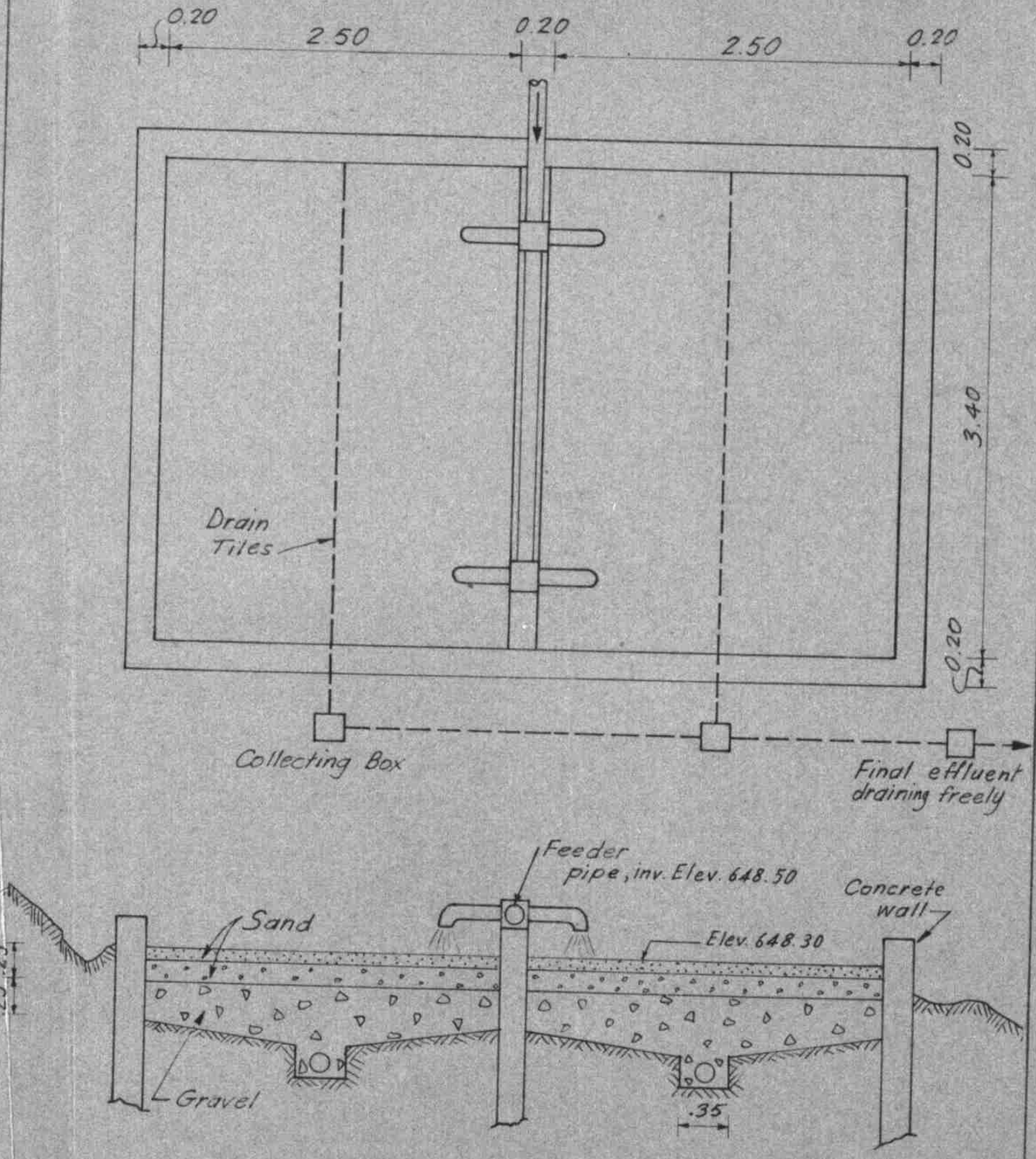
TREATMENT PLANT
SHUMAN POULTRAY PROCESSING PLANT

SECTIONS AND DETAILS OF
DORR-MINERALISATOR

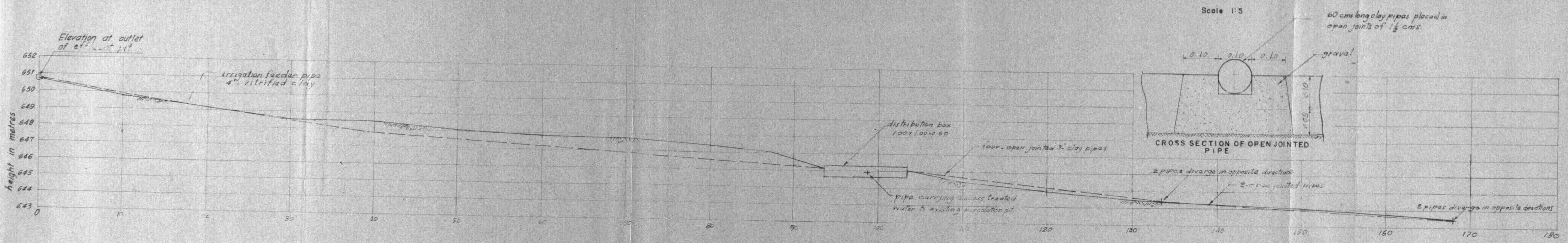
RAJA F. HALAZUN DATE:.........MAY 1964	DRG. NO.: ✓3 SCALE AS NOTED



Scale 1:40

DRYING BEDS RECEIVING SLUDGE FROM DORR—MINERALISATOR

Figure V.4



CROSS SECTION OF OPEN JOINTED PIPE

LONGITUDINAL SECTION OF IRRIGATION FEEDER PIPE

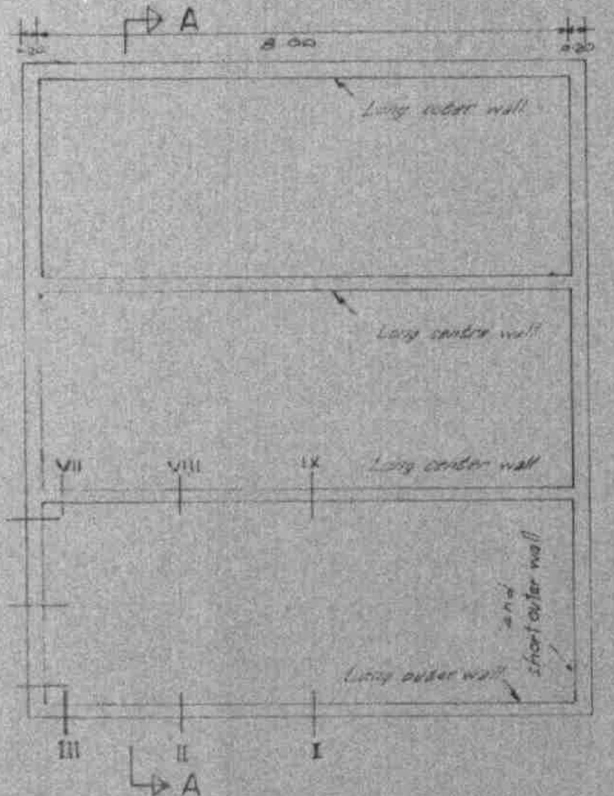
LEGEND

- – — – Elevation of invert of pipe
- —— Ground elevation.

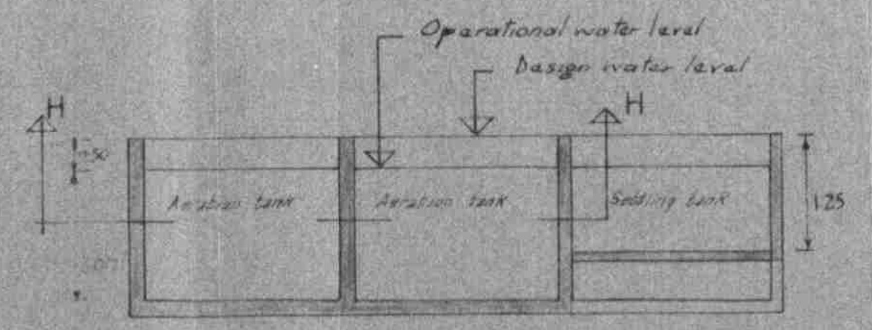
DWG. V. 5.

note:
All walls are
20 cm thick
Scale 1:100

REINFORCEMENT IN SECTION H-H



GENERAL PLAN OF TANKS
Scale 1:80



SECTION A-A
Scale 1:80

The two long outre walls have the same steel
The two long centre wall have the same steel.
The two end shortwalls have the same steel
Vertical steel is shown in the respective sections

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TREATMENT PLANT
SHUMAN POULTRAY PROCESSING PLANT

REINFORCEMENT OF AERATION AND SETTLING TANKS

RAJA F. HALAZUN DATE:.........MAY 1964	DRG. NO.:. . V. 6. SCALE AS NOTED

TABLE IV.1

Relationship of suspended solids in mixed liquor and sludge circulation.

Suspended solids content of mixed liquor mg/L	500	1000	1500	2000	25000	3000	3500	4000
Percentage of Average design flow	9%	20%	33%	50%	71%	100%	140%	200%

vi) Sludge Holding Tanks: 8 cu.ft. per capita (average sewage flow per capita is 100 gpd).[35,36] Such tanks are not required when aeration is by diffused air.

There is a considerable difference of opinion existing concerning the need for wasting of excess activated sludge. It is agreed however that wasting of excess sludge will improve the quality of the effluent.[24]

> "When separate sludge wasting is not practical, a clear effluetn with a low BOD can be produced until the mixed liquor suspended solids build up to equilibrium, after which solids are discharged in the effluent, lowering the effluent quality".[36]

It is reported that it is impossible to operate an extended system without sludge accumulation.[36]

A sludge holding tank is needed if an exceptionally high degree of treatment, in terms of suspended solids, is required.[24] The problem of control of mixed liquor suspended solids by sludge holding tanks is a basic factor in effluent quality.[39] Investigations on the nature of the accumulated volatile solids showed that these solids, which are mainly poly-saccarides but also contain fatty acids and organic nitrogen, accumulate because they are biologically inert to the organisms in activated sludge and that they, therefore, could be considered inactive mass.[39]

Since most of the solids lost in the plant effluent consist of this biologically inert organic matter, the effluent BOD is not as high as would be expected with comparable solids losses from a conventional activated sludge plant.[39] In cases where the effluent is received by water courses, these discharged solids could be of some pollutional effect. While in other cases where the effluent of the treatment plant is to be disposed of by land disposal methods, these discharged solids could be accepted

2. Efficiency of Extended Aeration Plants in the United States.

Efficiency figures of plants, that are of the same order of capacity as that of Shuman's plant would make it possible to estimate the expected quality of the plant effluent. Examples of reported efficiency are given in Table IV.2.[36]

TABLE IV.2

Efficiencies of a few Extended Aeration Plants.

Example	Design flow gal/day	Suspended Solids		Efficiency %	BOD		Efficiency %
		Raw	Final		Raw	Final	
Lorain, Sherwood	10,000	260	65	77	137	34	77
Green camp V.F. Goodrich La, b.	7,500	103	25	76	95	9	91
Mahoring Co. S.D.	12,000	95	7	93	164	15	92

Another report [37] includes data on an undefined industrial plant. The raw BOD was 281 mg/L and the final BOD 35 mg/L with 87.5% removal. The raw suspended solids were 335 mg/L and the final suspended solids were 79 with 76% removal. The suspended solids in the mixed liquor were 2530 mg/L. These results are average of 16 days of sampling with 5-6 samples a day.

These characteristics of raw waste-waters are obviously lower in the above examples than those obtainable from Shuman's plant. With proper design of the aeration unit the most optimum conditions can be maintained and efficiencies above 90% should be anticipated with complete mineralisation.

3. Cost.

(i) Initial cost: Generally, extended aeration plants are lower in first cost than any other type of waste-water treatment producing comparable results.[24,36] A report[24] on the cost of extended-aeration plants gives adjusted values for construction cost of 47 plants based on engineering estimates. These adjusted values are in accordance with the figures given in the "Engineering News Record-June 1960".

In Table IV.3 a few of the mentioned costs are indicated which correspond to plants with low capacities (in the order of the Shuman's plant).

TABLE IV.3

Costs of Some Extended Aeration Plants.

Plant No. Ref.	Type Facility Served	Design Flow gpd	Adjusted Plant cost $ 1000
15	School	8900	20.83
24	School	6000	25.83
27	Tourist	3000	7.20
29	Tourist	6500	6.3
41	Industry	7500	18.59
42	Unknown	6200	15.20

These values do not include the cost of sewers, lift stations or associated engineering and administrative expenses.

Lift stations are estimated at $ 0.06 - $ 0.13 per gallon of daily design flow. One plant reported $ 0.53 per gallon design flow.[24]

(ii) <u>Power Cost</u>: A value of $ 98.00 is reported[24] as power cost per million gallons of actual flow for a plant with design capacity of 12,000 gpd. This value is reported in a survey of 15 plants. A minimum value of $ 27 - pmg is given. This cost estimate is based on $ 0.02 per Kw-hr.

(iii) <u>Operator Man-hour per Week</u>: An average value of 4.2 man hrs/week is given for 9 plants with average capacities of 11,000 gpd.

In smaller plants where extended aeration units are generally lower in first cost than any other comparable plants, the operating cost may be sometimes higher.[36]

CHAPTER FIVE

SELECTION AND DESIGN OF THE PROPOSED TREATMENT PLANT.

I. SELECTION

General.

Due to the variety of treatment methods that can be employed in the treatment of poultry wastes, the selection of the most economical, efficient and practical unit needed involve the elimination of all other alternatives. In principles extended-aeration was chosen for the treatment of poultry wastes from Shuman's plant; but this selection would leave the engineer with a wide variety of acceptable choices all involving the extended aeration principle under various patented names.

Some of these alternatives are package units and some are built-in-sito. Each of the units has its own flow system and equipment features. Literature on these units is available in the catalogues of the various manufacturers and in recent journals on the subject.

Synopsis on Manufacturer's Package Aeration Plants.

A paper presented by Baker[26] gives a study on the performance of package aeration plants in Florida. The following manufacturer plants were studied:- Marlof, Chicago pump, Yeomans, Smith and Loveless, Infilco, Eimco, Walker, Water and Sewage,Inc., Water Conditioning,Dravo and some other local designs.

The determination of a superior unit was not possible, because of limited data. The design criteria of each of these units varied considerably from one another and the efficiency varied greatly from one location to the other, even when using the same manufacturer's equipment.

A. SELECTION OF EXTENDED AERATION UNIT

1. Biomac Extended Aeration Plant.[40]

This new design consists of a mild steel tank divided into an aeration section and a settling section. Air is supplied from two compressors, one running and one standby, via a set of air diffusors. Transfer of the mixed liquor to the settling section is by an "air lift" head via a simple pipe. The effluent is drained from the unit through troughs provided with scum baffles. The retention time can be varied by altering the diameter and/or length of air lift and also the quantity of air to it. Sludge return is accomplished through a simple pipe by hydrostatic pressure.

"Biomac is designed for treating the domestic sewage and certain trade effluents of small communities and industrial undertakings where small land requirement and low initial cost are important".

The Biomac is built in capacities ranging upto 30,000 gallons per day. Multiple units are recommended for ranges above that. However, this unit is primarily designed for domestic sewage. In addition, the air diffusors problems, air lift pipe and the difficulty of controlling the return sludge renders "Biomac" unadvisable for the Shuman's poultry plant.

2. Two Tier Extended Aeration Plant.

A new extended aeration treatment plant made by Mather & Platt Ltd. is being marketed. This Two Tier plant differs from other conventional extended aeration plants. It incorporates two sections in one steel package plant. The lower section is anaerobic at the bottom of which crude sewage is fed by pump or gravity. During its upward passage through the tank much of the solid matter is removed by a sludge mass that acts as a strainer. Some of the gases are dissolved in the liquid medium of the sludge while some are liberated to the atmosphere via gas vents. Sewage passes them upwards to the aeration section that runs around the periphery of the tank.

After extended aeration the mixed liquor is passed into a settling compartment and the clarified liquor becomes the effluent which can be discharged without any treatment.

The activated sludge settles to the bottom of the hopper in the settling compartment and is continuously airlifted bank to the aeration section where it is mixed with the up flowing raw sewage.

This plant claims a reduction in BOD of 60% before the sewage reaches the aeration section. Excess sludge must occasionally be wasted back to the anaerobic digestion section, but no sludge is discharged with the effluent.

The Two-Tier extended aeration plant is designed for domestic sewage and since it incorporates an anaerobic section, it is considered adviseable to avoid its use in treating the poultry waste waters of the Shuman's plant.

3. Defecamat.[41]

The "Defecamat" is a simple plant incorporating an aeration section and a settling section in one concrete pit. Mixed liquor flows from the aeration section around the settling compartment and into it through a "transfer part". In the settling compartment, the activated sludge and other solid matter settles to the bottom of the hopper from where it is re-cy through an air lift pipe to mix with the incoming sewage in a comminutor chamber situated above the inlet to the aeration section.

"Defecamat" is designed so that as fresh sewage enters the aeration section an equal volume of purified effluent is caused to over-flow from the final settlement hopper.

However, Peters Co. states that the Defecamat is designed primarily to treat domestic sewage and additional biological loading which poultry wastes would place or the plant, may impair its operating efficiency, and hence is not recommended for Shuman's plant.

4. Oxigest Extended Aeration Plant.[42]

"Oxigest" is a steel package plant incorporating the aeration tank and the settling basin in one unit. Waste water flows into an inlet channel to the aeration section being aerated with removable diffuser bars. The settling basin is created by a sloping partition-baffle separating it from the aeration section. The effluent from the settling tank is discharged over a multiple V - notched weir to an outlet channel. The hopper of the settling basin is open and the settled activated sludge and other materials is continuously in contact with the mixed liquor of the aeration section. Oxigest claims an exclusive automatic surface skimming mechanism which utilizes "return-flow" created by strategically located eductors placed on the partition baffle of the settling tank. The "return-flow" skims surface of the settling compartment by drawing the surface liquid through two side skimming troughs back to the aeration tank.

Although Smith & Loveless who manufacture the Oxigest claim a dependable treatment for some trade wastes in addition to sewage, Oxigest is expected to give lower efficiencies than the more exacting units in the case of highly organic wastes. The uncontrolled quantity of return sludge would definately affect the quality of the effluent and complicate its efficient operation. No efficiency figures are presented by Smith & Loveless for their design. Oxigest is not to be recommended for the treatment of waste waters for Shuman's poultry plant.

5. Dorr - Mineralisation Plant.[43]

A modern simple extended-aeration unit is produced by Dorr-Oliver. It is called the Dorr Mineralizator. This plant utilizes very simple mechanisms such as the ancient Archimidis screw lift pump, a mechanical brush aerator and a simple telescopic sludge return pipe. The Mineralizator is particularly applicable to smaller plants for treatment of industrial and domestic wastes.

Advantages of Dorr-Mineralisator include:[28,43] (a) The Dorr-Mineralisation plant is very low in installation cost as compared with other plants producing the same efficiency. (b) It requires minimum control and maintenance. (c) The screw lift pump has proved to be a very reliable pumping device for small installations. The open construction prevents any possibility of clogging in screw. Almost no control is required. (d) The power consumption of the screw lift is low and is almost independent of the capacity of the plant. (e) The expected efficiency is in the order of 90% BOD removal.

This simple and efficient package plant which is easily controlable is selected for the proposed treatment of the poultry processing wastes from the Shuman's plant. The Dorr-Mineralisation plant offering these advantages is described in detail in the following section.

Conclusions of Study

The following is an outline of the main conclusions arrived at in the preceeding study that led to the selection of the Dorr-Mineralisation plant as the major unit in the treatment of the waste waters from the Shuman's poultry processing plant.

a) Characteristics of the poultry waste waters indicate a high organic load (about 28.0 lbs of BOD and 18.4 lbs of suspended solids per 1000 chickens).

b) A study of the major current treatment methods of poultry processing wastes showed that extended aeration is recommended as the most suitable method of treatment for smaller installations having similar characteristics. (Expected daily flow is 30,000 litres per day).

c) A study of extended aeration units showed that the Dorr-Mineralisation plant avoids the problems incorporated in diffuser tubes and plates, pump clogging in sludge pumps. The initial and operating costs are very low. In comparison, simple Dorr-clarigester which provides clarification and sludge digestion in one tank, useing a chemical coagulant for better precipitation would cost 50% more than the Dorr-Mineralisation plant.[44]

B. THE PROPOSED DORR-MINERALISATION PLANT.

General.

Figure V.1 shows the flow in the units of the Dorr-Mineralisation plant. The effluent from the plant is collected and carried through an irrigational system of open pointed clay pipes.

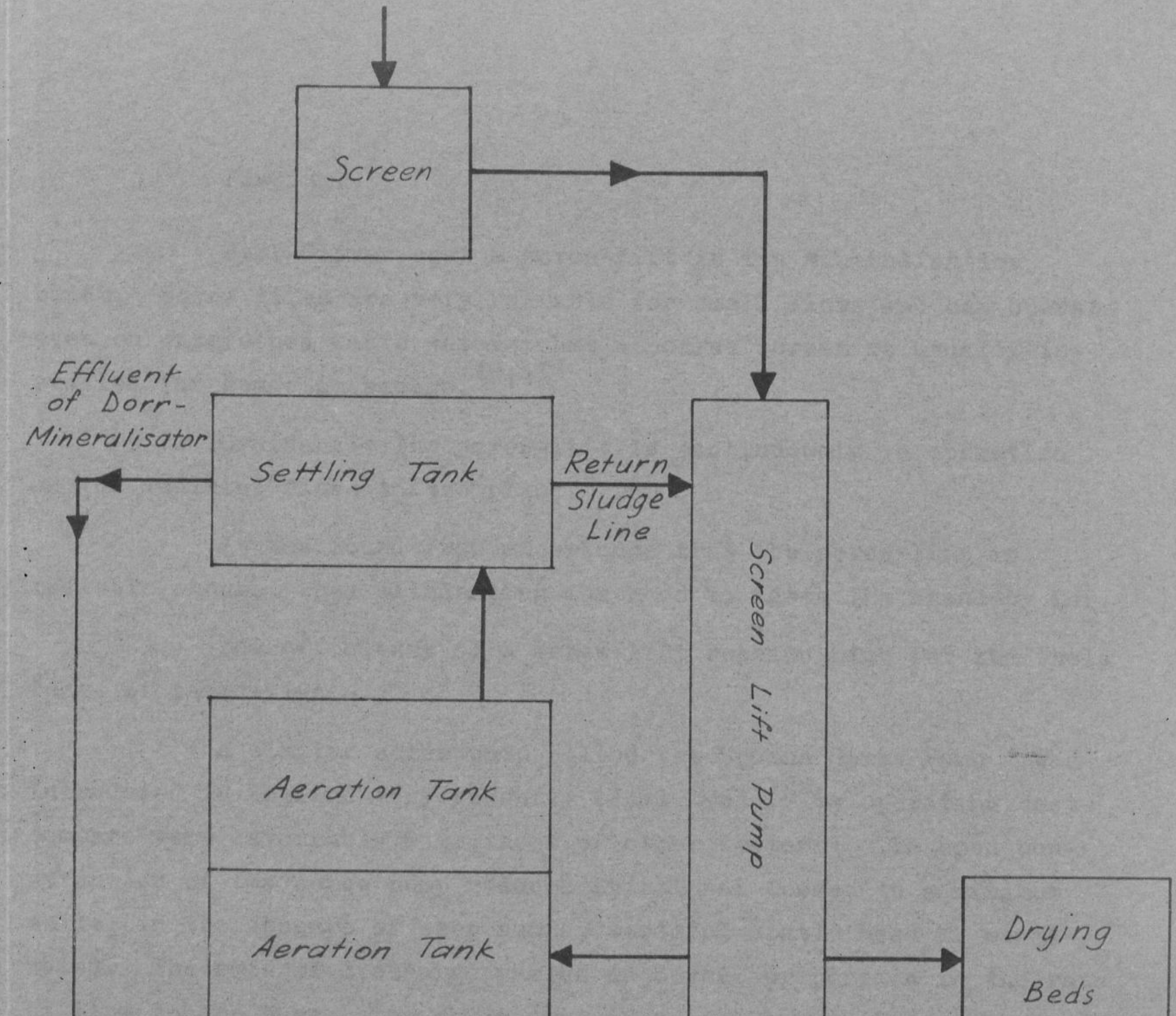
Description of Units

1. Flow in the Plant.

Raw sewage flows through the main sewer to the influent pit, it then flows through a pipe to the screw-lift pit where it is mixed with the recirculated sludge. The mixture is then transported to the aeration tank by means of the screw-lift. In the aeration tank, a brush aerator constantly circulates the waste water effecting its aeration. (Excess waste flows by gravity from the aeration to the settling compartment, where the settling takes place. Sludge from the settling basin is recirculated to the screw lift by means of a telescopic pipe. The effluent of the settling tank is discharged through the effluent launder to the irrigation system.

2. Screens.

A hand raked screen is usually recommended for smaller plants. When big solids are expected on automatic pulverizer is recommended. The sewer is usually provided with a gate valve which must be closed when excess sludge is pumped to drying beds by means of the screw-lift. There is no need for a gate valve in Shuman's plant since the flow is only for 5 hours a day and excess sludge can be pumped after the processing stops.



BLOCK FLOW LINE OF PROPOSED TREATMENT

Figure IV.

3. Pumping.

Dorr-Oliver uses a screw-lift in its Mineralisation plant. Screw lifts are very reliable for small flows and can operate even on unscreened waste waters; but a coarse screen is usually installed for domestic sewage.[40,43]

Ordinarily the screw-lift is continuously in operation as the influent flows to the plant.

It was found from experience that the screw-lift is reliable enough, thus eliminating the need to install a stand-by for.

The efficiency of a screw-lift remains high for the whole range of capacities.

A similar screw pump called the Spaans Screw Pump[40] was introduced in England very recently (Fall 1964)."Its operating costs compare very favourably with those of other systems. The open construction of the screw pump reduces frictional losses to a minimum while, in the absence of deep sumps, wasteful static head is eliminated. The rate of discharge varies in direct proportion to the rate of flow to the pump. The screw pump is reliable and there are no glands to be repacked; bearings are automatically lubricated and both screw and drive unit are extremely robust."[40]

An important feature of the screw pump is that when it is used for activated sludge return, the gentle action of the screw pump ensures that there is no liklihood of the sludge flock being broken up with possible loss of purification efficiency.

4. The Aeration Tank,

Consists mainly of a rectangular concrete structure that is divided horizontally by a wooden partition into two compartments. The Dorr-aeration brush installed at the influent side of the tank and rotating continuously, causes a strong circulation and hence aeration in the tank. The waste water and the sludge are swept away by the brush and flow through the upper compartment to the end of the tank and then back to the brush through the lower compartment. Oxygynation is brought about by the stirring action of the brush aerator elements.

For reduction of hydraulic losses the end of the aeration tank is provided with a steel guiding plate. The wooden partition is provided with an adjustable guiding body near the aerator.

5. The Settling Tank,

Consists of a rectangular tank of the same length as the aeration tank. The influent of the settling tank is located near the brush aerator, while the effluent launder is at the opposite end of the tank.

Settled sludge is transported to the hopper by means of a chain scraper that is continously in operation. Sludge is discharged from the hopper through a telescopic discharge pipe into the pit of the screw lift. The recirculated quantity of sludge can be adjusted by the telescopic pipe. The effluent launder discharges into the effluent pit via rubber pipe.

6. Sludge Drying Beds.

Some sludge drying beds must be provided for excess sludge. Generally 1 m^2 of drying beds per 25 inhabitants (consuming about 2000 gallons of water per day) is necessary for Dorr-Mineralisator.[43] The dried sludge will have useful fertilizing power and is usually recommended for agricultural use.

(iv) Irrigation Pipes and Percolation Pit: The effluent of the settling tank is considered the final plant effluent and is to be used for agricultural purposes.

The proprietor of Shuman's plant is interested in making use of part of the land for agricultural purposes.

Since the plant effluent is expected to be of acceptable quality, an irrigational system carrying this effluent is needed.

The irrigational and agricultural considerations are outside the scope of this project. However, the selection of the irrigation system will follow later.

II. DESIGN.

1. Basic Data

(i) Flow: It was stated that the flow from the Shuman's poultry processing plant is expected to be 30,000 litres per day, 5-hours a day, 6 days a week. The approximate estimated hydrograph of this was given in chapter three.

An average of 100 litres per minute and a peak value of 150 litres per minute (2.5 lps) is accepted.

(ii) The average summarized characteristics of the waste water from the Shuman's plant as found by laboratory tests, and as evaluated against accepted values in the literature, are given in Table V.1

TABLE V.1

Summary of Characteristics of Wastes from Shuman's Plant.

Test	Average Results
5-day-BOD	28.0 lbs/1000 chickens
Suspended Solids	18.4 lbs/1000 chickens
Dissolved Solids	24.3 lbs/1000 chickens
Volatile Solids	28.8 lbs/1000 chickens
Grease	1.3 lbs/1000 chickens
Total nitrogen	3.8 lbs/1000 chickens
pH	6.2 lbs/1000 chickens
Alkalinity	400 mg/L
Turbidity	600 mg/L

(iii) The design of the units of the proposed treatment plant is based on:

a) Accepted criteria for design, both emperical and rational.

b) The Dorr-Oliver recommendations for their Dorr-Mineralisator.

c) Deductions on the best criteria suitable for the particular case of waste waters from the Shuman's plant.

(iv) Structural design of the tanks is given at the end of the sanitary hydraulic designs

All drawings of the desinged units are attached at the end of this chapter.

2. Design of Units.[43]

(i) Influent Pipe, Influent Pit and Screen: (Dwg. No.V.2) Since the peak flow to the plant is very low(2.5 lps) the minimum size of sewers of 6 inches, is used for the influent pipe.[19] This minimum size is stipulated to avoid the hazard of clogging.

The influent pit design is normally done to ensure optimal velocities ahead of and through the screens. For normal sewage the horizontal velocity through the pit is stipulated by certain authorities to be a minum of 1 ft. per second, in order to avoid undesirable sedimentation in the screen pit.[19]

Since deposition of solid in the influent pit channel, cannot form a serioud problem with the small estimated flows at the Shuman's plant, and since the flow is only for 5-hours a day-allowing for daily cleaning of the cannel, a low velocity can be tolerated.

Dorr-Oliver allows a depth of 33 cm above which the centre line of the influent pipe is located. For small flows Dorr-Oliver suggests a section of 0.60 m x 1.00 m for the pit. The depth of the pit over the influent invert level is 1.50 m which usually allows for the accumulation of solids on the screens. It will be seen below that only a very small portion of this is required for normal flows.

Screens. (Dwg. No.V.2,3)

The size of the screen is normally designed by adjusting the velocity through the openings to comply with the optimal velocity of the waste water through the screen. A limiting maximum velocity of 2 fps is required by some authorities.[20] However, others require that the velocity normal to the plane of the screen should not exceed 0.5 fps in order to prevent the forcing of objects through the screen[19]

Generally speaking, fine screens were considered the most effective mehtod of screening poultry processing waster waters. Such fine screens discussed in chapter three, caused some operational troubles. Initial and operating costs are definately higher than those for medium sized fixed bar racks.

In domestic sewage, medium sized screens with openings of 1 inch or less remove normally 4 to 12 cu.ft. of screenings per million gallons.[21] Fine screens remove 10 - 25 cu.ft. of screenings per million gallons of flow. Therefore, medium fixed screens with 1 cm. openings are proposed for the treatment of poultry processing wastes from Shuman's plant. The screen width is equal to the width of screen pit channel.

The size of the screen openings will affect the velocity through the screen by the relation Q = VA. However, the lower the velocity, the greater the volume of screenings to be removed from the waste waters, and the greater the amounts of solids deposited in the channel. Since as explained above, the amount of sedimentation of solids in this particular case is small, lower velocities would give a better efficiency of the screen at no material expense or harm to the plant.

Velocity and Depth.

Maximum flow is 2.5 lps. Assume a velocity of 10 cm. per second through the screen which is about 1/3 of what is usually recommended.

Assume bar opening to be 1 cm. and a bar spacking of 2 cm. . .

$$2.5 \times 1000 = 10.A$$

$$\text{or} \quad A = \frac{2500}{10} = 250 \text{ cm}^2$$

With 30 openings, each 1 cm. wide the depth of water should be 250 = 8.33 cm. The Dorr-Oliver screen extends much more as shown in the drawings, allowance being given for deposition of screenings, free board and shock loads.

At this depth the velocity in the channel of the influent pit is $\frac{2500}{8.33 \times 60}$ = 5.0 cm/sec. At lower flows, the velocity and depth will lower, and hence the deposition on the screen will be higher.

Raking.

Manufal **raking** of the screen is recommended because it is cheap and easy to perform.

The volume of **rakings** expected with the use of 1 cm. medium bar screen is estimated from a graph reported by Hodgeson.[19] A screen with an opening of 1 cm. (approximately $\frac{3}{8}$ inches) is expected to yield more than 10 cubic feet of screening per million gallons. This is equivalent to 75 litres of screenings 1000 m^3 of flow and hence with a daily flow of 30 m^3 from Shuman's plant, the expected screening volume is over 2.25 litres per day. Lower velocities might raise this value appreciably.

It was found desirable to place the screen bars at a slope to cause the screening to accumulate near the top and to obtain a low velocity through the screen.[19] Small slopes were found to make the screens self-cleaning. As the screen clogs the increasing head of waste water will push the accumulated screenings up to the screen. Location of the perforated platform is shown on the drawings.

Rectangular bars are usually placed at $30^\circ - 60^\circ$. Since the flows are small, and the velocity through the screen is small the steeper slope of 60° is proposed. **Raking** is done along the slope of the screen collecting the rakings on the perforated platform at the tope of the screen.

Rakings collected on this platform should be taken after the clean-up of the days work. The rakings should be incinerated with the solid wastes from the evisceration process.

The section of the bars is recommended to be 1 cm x 2 cm.

Hydraulic Losses.

The loss in head through such racks is estimated by Kirsher[19] emperical equation $h = B\,(w/b)^{4/3}\,h_v \sin\theta$ where h is the loss of head in feet, w is the maximum width of the bars faceing the flow, b is the minimum width of the clear openings between pairs of bars, h_v is the velocity head in feet of water as it approaches the rack (face velocity), θ is the angle of the rack with the horizontal and B is a bar shape factor. For sharp-edged rectangular bars B is 2.42. Then $h = 2.42 \times (1)^{4/3} \times h_v \times 0.866 = 2.1\,h_v$. Since the face velocity is 10 cm/sec. (0.33 ft. approximately), $h_v = (0.33)^2 = 0.0017$ ft. and $h = 2.1 \times 0.017 \times 30.4 = 0.0107$ cm. This is the case when the rack is clear. The loss in head is negligible. As the screen clogs the velocity head increases and the hydraulic loss increases accordingly ($2.1\,h_v$).

(ii) Pipe Leading to the Screw Lift Pit: (Dwg. No.V2,3)

A vitrified pipe is normally employed by Dorr-Oliver for Dorr-Mineralisator. Such a pipe avoids the danger of corrosion, erosion and give generally satisfactory performance. An advantage of the vitrified clay pipe is its good hydraulic properties due to its smooth, impervious surface.[19] A disadvantage is its brittleness.

The velocity of flow in the sewer pipe of 1 lps should be available at minimum flows and 2 lps when flowing full.

For a vitrified pipe in good condition N in Manning formula, $v = 1.486/N\,r^{2/3}\ s^{1/2}$ is 0.012 in fps For a minimum velocity of 2 lps, when flowing full the capacity of the pipe is 0.393 cubic feet per sec.

or 11.1 lps. Since the maximum flow from the plant is 2.5 lps, this pipe leading to the screw lift pit will never flow full. The minimum slope for the pipe flowing full to get a velocity of 2 lps is 4.18×10^{-3}. With this slope and with a flow of only 2.5 lps the pipe will be flowing partly full. Some hydraulic characteristics of the partly filled pipe are found using a graph presented by Fair and Geyer.[15]

Considering, q/Q = flow in partly filled pipe/flow when full, d/D = height of water in pipe/Diameter, N/n = friction coefficient/roughness coefficient and using $N/n = 1$, v/V = velocity when partly full/velocity when full, r/R = ratio of hydraulic radii, partly full/full.

Then for $q/Q = 2.5/11.1 = 0.225$
$d/D = 0.32$
$v/V = 0.80$
$r/R = 0.70$, but $R = D/4 = 1.5''$, then $r = 1.05''$

and the velocity is $0.80 \times 2 = 1.6$ lps which is acceptable. Checking with Manning formula for $r = 1.05''$, and $s = 4.18 \times 10^{-3}$, v is also found to be 1.6 fps.

Since the flows and hence velocities encountered at Shuman's plant are low, it is more important to consider maximum velocities. A maximum velocity of 8.0 fps is usually recommended. For a maximum flow of 2.5 lps and a velocity of 8 fps the required slope is 0.05. Since the length of pipe is expected to be small (about or less than the length of the settling tank) this slope is found acceptable. The velocity in this pipe is always less than the 8 fps except at peak flow. The flow during the remainder of the 5 hours flow approaches zero at the end of the processing time. The peak load will provide a flushing velocity for the pipe.

(iii) Pumping[43]: (Dwg. No.V.2,3)

The characteristics of the screw lift pump include the following:-

The capacity of the screw-lift is almost directly proportional to the number of revolutions it turns. The maximum head to which the screw pump can be used is 6-7 m. The concrete gutter through which pumped sewage flows should be extremely smooth.

Due to the fact that the screw-lift maintains a good efficiency at part of the full capacity, it compares then, with two or three centrifugal pumps. A wet well is not needed.

The screw lift has a special advantage if the driving is done by a V-belt. The capacity can be changed by just changing the diameter of the pulley.

A study of the characteristics of the pump has led to the following conclusions:

a) The capacity for smaller heads remains practically constant.

b) The highest efficiency lies at the point of full submergence of the screw tip.

c) The capacity only decreases when the water level falls below the point of full submergence.

d) For capacity of 25-100% of the full capacity the efficiency is not greatly affected.

A screw-lift with a small diameter should have a high number of revolutions, while big screw lifts revolve slowly.

The number of revolutions is normally taken from the formula

$n = \frac{50}{\sqrt[3]{D^2}}$ where, n is the rpm and D is the diameter of the screw in meters. A diameter of 0.3 m. is selected.

$$n = \frac{50}{\sqrt[3]{D^2}} = \frac{50}{\sqrt[3]{0.09}} = 112$$

Capacity of the Screw Lift.

The capacity of the screw lift is practically independent of the discharge head as appears from the formula $Q = \& q\, n.D^3$ where & is a constant value = ± 1.15, q is a coefficient of the screw shape which is dependent on the pitch S, the ratio of shaft diameter per screw diameter, d/D ; and on the mounting angle.

Using a pitch = diameter D, d/D = 0.5

Assuming a mounting angle of 30°[43] q is equal to 0.250

$$Q = 1.15 \times 0.250 \times 112 \times (0.3)^3$$
$$= 0.86\ m^3/min. = 51.6\ m^3/hr.$$

Since the average flow is 6.0 m^3/hr. only and the flow from the returned sludge is expected to be in this order too, a capacity of 51.6 m^3/hr. will be too great, and the efficiency will be very low. To increase the efficiency the rpm is decreased. Dorr-Oliver suggests using n = 65 rpm where the flows are in the order of those present at Shuman's plant. Normally, screw pumps operate in the region of 50 r.p.m.[40,43]

Using n = 65, rpm, Q from the above equation is 0.5 m^3/min, or a capacity of 30 m^3/hr. Since for 25-100% of Q the efficiency does not vary considerably, the expected efficiency shall be high.

Efficiency of Pump.

The efficiency of the pump is found from the emperical equation:

n = (1 - a - b - c) where a is the hydraulic loss
b is the leakage loss
c is the outlet loss
d is the mechanical loss

where $a = e\, n^2\, D.\frac{L}{H}$, e = screw constant value equal for this screw to 14×10^{-6}, H = static head in m., L is the length of screw in meters (established later) $b = \frac{L_2}{\&.n.D.}$, where L_2 is another screw constant value equal in this case to 2.84 $c = 14.1 \frac{S^2 n^2}{H} \times 10^{-6}$, all nomeclatures defined before.

The mechanical losses depend upon rpm and the bearings. A mechanical efficiency of 90% is established.

$$\text{Overall efficiency} = 0.90 (1 - a - b - c)$$

$$a = 14 \times 10^{-6} \times (65)^2 (0.3) \frac{L}{H} = 27.3 \times 10^{-3} \frac{L}{H}$$

$$b = \frac{2.84}{1.15 \times 65 \times 0.3} = 0.123$$

$$c = \frac{14.1 \times (0.3)^2 \times (65)^2 \times 10^{-6}}{H} = \frac{8.2}{H} \times 10^{-3}$$

Final evaluation of efficiency can be made after the determination of L and H and it is already seen that the efficiency is very high since (a + b + c) for normal values of L and H are rather low compared to 1, and the efficiency is expected to be in the neighbourhood of 80% or more.

The required capacity used is determined after the rate of recirculated sludge has been established in accordance with the aeration requirments of the extended aeration system.

Power Requirement.

Dorr-Oliver has found that a motor of 1½ HP with flexible coupling is needed to provide the power requirment for the 30 m^3/hr screw lift pump.

(iv) Aeration Tank: (Dwg. No.V.)

Most of the various basic design criteria of the aeration tank were given previously under the evaluation of extended aeration. The final design of this unit is done by comparison of these various criteria. Each of these criterion give a different tank volume.

The influent 5-day BOD per 1000 chickens processed is 28 lbs and hence the influent 5-day BOD per day is $28 \times \frac{3000}{1000} = 84$ lbs, the influent suspended solids per day are 18.4 x 3 = 55.2 lbs, the influent dissolved solids are 24.3 x 3 = 72.9 lbs per day and the influent volatile solids are 28.8 x 3 = 86.4 lbs per day.

Screening is expected to reduce these loadings by more than 10%, as explained in chapter three, and hence the screened influent would carry the following loadings: 75 lbs of BOD per day, 55 lbs of suspended solids per day, 65 lbs of dissolved solids per day and 77 lbs of volatile solids per day.

a) Considering the first criterion, usually applicable to domestic sewage, of 24 hours detention period the aeration tank volume is $\frac{30,000}{1000} = 30$ m^3 excluding the recirculation volume. This criterion has already been outdated, since it does not consider the loading of the influent waste water; and the consideration of new parameters dealing with other major variants is more scientific.

b) 12.5 pounds of BOD/1000 cu.ft. of aeration volume. The volume of the aeration tank will then be $\frac{75}{12.5} \times 1000 = 6000$ cu.ft. $= 6000 \times \frac{28.32}{1000} = 170$ m^3. The reason for this big difference in tank volumes between (i) and (ii) is the fact that this criterion in (ii) was designed with domestic sewage characteristics in mind. The high strength of the poultry processing waste waters caused this high deflection.

c) Dorr-Oliver suggests a retention of about 1.25 days in the aeration tank, excluding return sludge volume, and thus the tank capacity should be 37.5 m^3.

d) Haseltine[38] recommends that the aeration tank should carry 10 lbs of solids per pound of daily BOD input.

The suspended solids to be maintained in the mixed liquor (M.L.S.S.) is assumed, and normally ranges from 500-4000 mg/L[38]. Assuming an MLSS = 3500 mg/L the solids in the total tank of volume, V, are $\frac{V \times 8.34 \times 3500}{10^6}$ lbs. Since 10 lbs of solids are to be maintained per 1 lbs of BOD, the total solids required are 10 x 75 = 750 lbs, hence the equation:

$$\frac{V \times 8.34 \times 3500}{10^6} = 750$$

and Vis then 92 m^3.

e) Fair and Geyer[15] present mathematical relationships to find the aeration tank volume:

Assuming a required efficiency of P_2, Fair and Geyer define a loading intensity as W.t which is weight of sludge to be returned, W; multiplied by the detention time, t, in the aeration unit: $W.t = \frac{\text{BOD in lbs/day}}{4200} \times \frac{(P_2)}{(100-P_2)}^{2.38}$. For a required efficiency of 80%.

$$Wt = \frac{75}{4200} \times \frac{(80)}{(20)}^{2.38} = 490 \text{ lbs - hrs.}$$

Defining the percentage suspended solids in mixed liquor as, P_w and assuming it 0.35 (3500 mg/L) Fair and Geyer derive the following equation for the detention time:

$$t = \frac{538}{5} \sqrt{\frac{w.\ t}{1000.\ I.\ P_w}} \quad \text{days}$$

where I is inflow in gallons per day for five hours of daily operation hence,

$$t = \frac{538}{5} \times \sqrt{\frac{0.49\ (3.78)}{30{,}000\ (0.35}} = 1.35 \text{ days}$$

The volume of the tank to take the inflow of 30 m^3 per day is then 1.35 x 30 = 40.5 m^3 excluding the volume of returned sludge.

Rate of Recirculation of Sludge.

The nominal design rate of sludge return expressed as a percentage of the average desing rate of flow was given in a table as prepared and estimated by Haseltine. This rate is a function of the concentration of suspended solids in the mixed liquor (MLSS), the sludge volume index of those solids and the time those solids are retained in the settling tank. From that table, and for the assumed value of MLSS of 3500 mg/L the nominal return rate is 140%.

This value is justified by the following formula as presented by Krauss.[19]

$MLSS = \frac{V \times 10^6}{I_v\ (1 + v)}$, in which v is the ratio of returned sludge and I_v is calculated:

$$\frac{\underline{1000 \times \text{vol. of floc settling in 30 min. from 1 litre}}.}{\text{MLSS}}$$

For extended aeration Haseltine[38] has found that for average conditions the sludge volume index I_v is 167.

Then from the Krauss formula

$$3500 = \frac{v \times 10^6}{167\ (1 + v)}, \text{ and } v = \frac{0.58}{0.42} = 1.40 \text{ (check)}$$

Hence, the volume of daily returned sludge is accepted to be 140 % of the flow.

Summary of Tank Volumes (a) to (e):

a) 30 m^3 + 1.4 (30) = 72 m^3

b) 170 m^3 (criterion included volume of return sludge).

c) 37.5 + 1.4 (37.5) = 90.0 m^3

d) 92 m^3 (criterion included volume of return sludge

e) 40.5 + 1.4 (40.5) = 96 m^3

Tank Dimensions.

Dorr-Oliver suggests the use of two aeration tanks when the volume exceeds 50 m^3 in the Dorr-Mineralisation. This is a result of experience in the efficiency of mechanical brush aerator that Dorr-Oliver uses. Considering the volumes as found from (c), (d) and (e) above, a volume of 96 m^3 will be adopted. Assuming a width of the aeration tank of 3 m, the depth is approximately chosen from the established formula[21]; $D = \frac{W}{3} + 5$ in which D is the depth and W is the width, both in ft. Hence for W = 3 m = 9.84 ft.

$$D = \frac{9.89}{3} - 5 = 3.28 + 5 = 8.28 \text{ ft.} = 2.5 \text{ m.}$$

Dorr Oliver suggests the use of shallower tanks for the proper oxygynation by the brush aerator, and hence a depth of 2.0 m is selected.

The tank length is then $= \frac{1}{2} \times \frac{96}{3 \times 2} = 8.0$ M.

Brush Aerator.

The Dorr-brush aerator provides a simple mechanical device for aerating the waste water. The **width** of the Dorr-brush aerator is equal to the width of the aeration tank.

Mechanical aerators in common use are proprietory devices each with its unique and patented characteristics.[19] The Dorr-brush aerator patented by Dorr-Oliver is expected to provide the air requirement in the Dorr-Mineralisation plant. The air requirement is recommended to be about 2100 cu.ft. per pound of BOD entering the tank daily. Haseltine proposed that in general, wheather diffused air or mechanical aeration is used , 2 mg/L of dissolved oxygen should be maintained in all parts of the aeration tank except immediately beyond the inlet. Haseltine also stipulated that velocity of movement should be maintained so as to bring sludge particles into intimate contact with all portions of sewage and to prevent deposition in any part of the aeration unit.

The Dorr-Mineralisation plant divides the aeration tank by a false wooden bottom so that the brush aerator will sweep away the sewage and sludge through the upper compartment to the end of the tank and then back to the brush through the lower compartment.[43]

The velocity of the waste water in the tank will be over 25 cm/sec.

The power requirement is affected by the length of the motor and the submergence depth. To decrease this power to an absolute minimum the level in the aeration can be adjusted by changing the position of the effluent launder in such a way that the oxygenation capacity and the propelling action of the brush is just sufficient.

In completely submerged mechanical aerators the power requirement is greatly affected by the depth to which the aerator is submerged and the peripheral speed.[46] The peripheral speed is a major factor in the oxygen absorption efficiency.

Dorr-Oliver has found that a motor of 3 HP provides the required power for rotating the brush aerators to produce effective oxygenation of strong wastes in the proposed aeration tanks.

(v) Settling Tank[43] (Dwg. No. V)

Dorr-Oliver proposes a settling tank with the same length and width as the aeration tank. The minimum settling tank depth allowed for in the Dorr-Mineralisator is 1.25 m. (equivalent to 4.1 ft.). This is much lower than the generally accepted minimum of 8 ft.[38] This will give a capacity of $8.0 \times 3.0 \times 1.25 = 30\ m^3$ or an average detention time $t = \frac{30 \times 5}{30 + 1.4(30)} = 3.56$ hours.

The settling properties of the influent to the settling tank are very bad due to the change from activated sludge to mineralized sludge. The reasons for the bad settling properties are due to the fact that extended aeration causes the activated sludge floc to become very small and compact, which, although nitification may be complete, will not permit quick settling. Furthermore, some of the floc is apparantly broken up into minute particles which might not settle in the final settling tank, even though the main body of the sludge settles very rapidly. Hence the high detention time is justified.

A hopper of 3.0 x 1.10 x 0.75 is used by Dorr-Oliver for this size of settling tanks. The hopper is sloped to 25 cm.sq. from its four corners as shown in the attached drawings.

Sludge Scraping Device:

A mechanical chain sludge scraping device is used. The chain scraper has 20 cm. deep wooden scrapers that run across the settling tank, and are 1.0 m c.c. The chain moves over three sets of pulleys around the tank. The scraped settled solids are moved into the hopper.

A driving motor of ½ Hp was found by Dorr-Oliver to provide the necessary power for best scraping efficiency.

Telescopic Sludge Return Pipe:

Sludge return to the screw lift pit is achieved through a telescopic pipe which is regulated to give the required volume of return sludge. It is a 4-inch pipe that runs from a point 10 cm. above the bottom of the hopper through the bottom of the screw pit. The flow is controlled through a handle, at the top of the screw lift pit, that connects to a tapered piston shaft placed inside the coming pipe. Recirculated sludge flows, with the pipe partly opened, to give the required volume of return sludge.

The required average volume of return sludge is 1.4 x 6.0 = 8.4 m^3 per hour or 2.35 lps.

Assuming the telescopic pipe to be one-third open the discharge is $Q = C_d \cdot A\sqrt{2gh}$, where C_d is $C_c \times C_v$. When the pipe is one-third open, C_c is approximated to be $C_c = \frac{A}{A_*} = 0.3$ and $C_v = 0.80$. Hence $C_d = 0.3 \times 0.8 = 0.24$. For Q = 2.35 lps,

$$2.35 = 0.24 \times \frac{1}{3} \times \pi \times \frac{(15.6)^2}{4} \times \sqrt{2 \times 980.}\ \sqrt{h}$$

or, h = 12.5 cm. (based on a constant level in the settling tank).

The variation in opening the recirculation sludge pipe will be adjusted with experience to give a proper sludge return rate, based on the calculated 140% rate that was found before. It was shown that this rate depends on the sludge index of the activated sludge in the aeration tank. The operator will find out with practice the optimal sludge index and optimal rate of return sludge as regulated through this telescopic pipe. These values will vary with varying strengths of inflow.

Scum Return Turnable Pipe:

The Dorr-Mineralisation plant employs a turnable pipe for scum return. The pipe is placed at the effluent side of the settling tank. Its standard size is a 12-inch pipe connected from one end of the settling tank to the other with an arc opening of 60°.

The opening is cut almost all along the pipe leaving about 12 cms on both sides. The lower lip of the opening is adjusted to the level of the water. Scum is collected in the pipe as the chain is circulating around the tank. The scum pipe returns the collected scum to the influent pit and is screened again to the plant with the influent.

Inlets and Outlets of Aeration and Settling Tanks:

Inlet to first aeration tank: The screw lift pumps the influent and recirculated sludge to the aeration tank through a rectangular channel. A sufficiently high velocity is usually recommended through the inlet. For a peak flow of 2.5 lps the pumped flow is $2.5 + 1.4\ (2.5) = 6.0$ lps; assuming the calculated recirculation rate of 1.4. The inlet velocity is assumed to be at peak flow 30 cm/sec., hence a section of $\frac{6000}{30} = 200$ cm^2 is needed. With a width of 20 cm, the depth is 10 cm. Allowing a free board of 10 cm the requires section of channel is 20 cm x 20 cm in section.

Inlet to second aeration tank is done through a circular opening 30 cm in diameter placed in the partition wall between the two tanks as shown in the section drawings attached.

No cross circulation can take place since the inlet gives directly to the continuously moving aerator that keeps the whole body of water in circulation.

Inlet to settling tank is done through a turnable level control pipe, 30 cm in diameter that connects from one end of the tank to the other. It has an arc opening of 30° that extends all along the pipe; thus ensuring a low inlet velocity. Head losses are function of inlet velocities and hence such losses are kept to a minimum.[47]

For sharp inlets the head losses, other than those due to friction are about $0.5\ \frac{V^2}{2g}$.[47] With a maximum velocity of inlets to aeration tank of 30 cm/sec., the head loss is about $\frac{0.5\ (30)^2}{2 \times 980} = 0.25$ cm; which is very low. All inlet head losses are expected to be lower than this.

Effluent Launder:

The effluent from the plant is carried away through a channel which is placed at about 15 cm from the side of the settling tank that is furthest from the inlet. It extends from one side of the tank to the other with a length of 3.0 m. The effluent collects in the launder channel from both of its sides. Since the effluent is approximately equal to the influent (the difference is that part going to the sludge drying beds) a channel 20 cm x 10 cm deep, and a pipe of 4-inch minimum dimension are accepted to take maximum out flow of 2.5 lps.

Dorr-Oliver suggests the connection of the effluent pipe with a rubber hose to adjust the level in the system to produce optimal power requirements of the brush aerator by raising or lowering of the water level. The sides of the launder channel act as an over-flow weir.

(vi) <u>Drying Beds</u>: Drying beds are proposed to take the excess sludge in the plant. This excess sludge has led to the use of sludge holding tanks. These tanks are usually needed if the effluent is to be received by a body of water. Since the effluent is to be used for irrigation at its best, no such holding tanks are warranted. Excess sludge is just pumped unto the drying beds.

Using the recommended value of 1 m^2 per 25 people as a design criterion for the drying beds and using the accepted value of soilds production of 0.2 lbs per capita per day,[21] the population equivalent on that basis will be equal to total solids per day divided by 0.2; $\frac{18.4 + 24.3}{0.2} = \frac{42.7}{0.2} = 213$ people.

$$\text{Area of drying beds needed} = \frac{213}{25} = 8.5 \text{ m}^2$$

With a width of 2.5 m, the required length is 3.4 m.

Two units are recommended for flexibility of operation for a cleaning. The sludge filter beds are made of 25 cm of coarse and under-lain by 30 cm of graded gravel ranging in size from 3 mm to 8 mm at the tope to a size of 20 mm to 40 mm at the bottom. The underdrains are 15 cm drain tiles placed in trenches with open joints. The side wall and partitions are of 20 cm concrete walls, extending 20 cm above the sand surface as a free board. The drain tiles slope at about 5%.

<u>Gates</u>.

Two simple sliding steel gates should be placed at inlet of first aeration tank and at the outlet pipe discharging to the drying beds.

When the accumulated sludge is being discharged unto the drying beds the inlet to the aeration tank is closed and the outlet to the drying beds is open, and vice-versa.

(vii) Irrigation System: The final effluent of the settling tank of the Dorr-Mineralisator is discharged to an effluent pit that collects the water and passes it to the irrigational system.

A detention of the effluent for a period of 10 minutes is allowed. Hence considering a flow of 5 m^3/hr. (disregarding all losses of amount pumped to drying beds, conveyance and evaporation), the volume of the pit is $\frac{10}{60} \times 5 = \frac{5}{6} m^3$. With a section of 1.0 m x 1.0 m a depth of 85 cm is required.

Irrigation of the adjacent land is attained by leaching through open-jointed clay pipes. An irrigation of feeder pipe runs down from the effluent pit to a distribution box out of which four open-jointed clay pipes collect the treated water. The feeder pipe is a four inch pipe sloping down a distance of 9.5 meters along a steep slope of about 0.50 running almost over the ground level. The distribution box is 1.00 m x 1.00 m x 0.50 m, which will collect the water, reduces its velocity and distributes it to the leaching pipes. The open-jointed pipes are 3-inch pipes, 60 cm long placed at about 1½ cm openings. The top third of the joint is covered with tar paper to prevent soil and dirt from entering the irrigation pipe.

The open-jointed pipes are placed in gravel to improve the percolation efficiency andhence obtain better leaching. The longitudinal section of the irrigation feeder pipe and a cross section of the open-jointed clay pipes are attached.

Irrigation is attained by both leaching and "wild" surface floading with the remaining part of water.

The quality of water is definately good for irrigational purposes for the following reasons:-[48] The dissolved solids in water used for agricultural purposes should not be more than 2100 ppm. Water with dissolved solids of 175 ppm or less is designated as excellent, 525 ppm good, 1400 ppm permissible, 2100 doubtful and unsuitable over 2100 ppm.

Since efficiency of the plant is expected to be about 80% and the screened solids are 65 lbs per day the expected dissolved solids concentration is $\frac{20 \times 65 \times 3.78 \times 1,000,000}{100 \times 8.34 \times 1000 \times 30} = 194$ ppm. Hence the dissolved solids concentration is within the excellent-good range.

The chloride concentration should be less than 20 ppm. for agricultrual purposes.[48] Since the process water is potable and since the process do not contribute to the chloride content, the treated water is considered adequate for irrigation.

It is expected that the nitrogeneous matter nitrified to nitrates will be present in the effluent. Since nitrates have a good fertilizing power, and because of the above mentioned reasons the effluent water is generally expected to be good for agricultural use.

Since there might occur a time when water is not needed for agricultrual purposes and because of the low elevation of the present percolation pit, excess water is returned to the percolation pit. This will be just a precaution measure and might not arise except when the water is temporarily not needed for irrigation.

3. Operation of System.

The influent carries the waste water continuously from the bottom of the present septic tank, acting as an equlizing tank, to the influent pit.

The treatment plant of the waste water from Shuman poultry processing plant will then operate as follows:-

a) Units and Hours of Operation:

All the units involved including screening and screen raking, screw-lift pump, brush aerators, mechanical scraper and telescopic return sludge pipe will operate continuously during processing hours between 8:00 - 13:00 hours.

At 13:00 hours the sliding gate of the first aeration tank is closed and the gate to the drying beds is opened; and the excess sludge in the settling tank hopper is returned to the screw lift pit and is pumped by the screw lift to the drying beds. A little amount of excess sludge is expected.

At the same time, 13:00 hours, the brush aerators will start operating in cycles as explained below. Since the aeration tanks contain a mixed liquor of high solids it cannot be expected to be retained in the aeration tanks for the next day's inflow since settling will occur and the brush aerator will not function properly anymore. At this stage the inflow is supposed to be completely oxidized. Since there is a possibility that a small portion of the organic load might not then be fully oxidized yet due to in-experience in proper operation and since the mixed liquor cannot stand still for 19 hours, aeration in cycles of 30 min. and a rest of one hour seems reasonable. Plain aeration of the mixed liquor with no inflow and no return of activated sludge will definately improve the quality of the effluent. In general, it has been observed that in presence of high concentrations of protein and certain other organics the observed transfer rate of oxygen to the liquor is greater than in pure water and hence, the remaining organic matter, will be oxidized.[49]

b) <u>Maintenance</u>:

The screens, influent pit and screw lift should be cleaned of any feathers or solids that might have collected on them during operation. This should be a daily inspection procedure.

In the first few days of the treatment plant operation, some tests on mixed liquor suspended solids should be made to properly adjust the sludge return rate. This should become a monthly or by-weekly procedure. The mixed liquor suspended solids should not be over 3500 ppm.

Dissolved oxygen in the aeration tank should be measured continuously and maintained at a minimum of 2 ppm at the effluent to the settling tank.[19] This minimum should also be maintained in the settling tank.

If frothing occurs the addition of 1 ppm kerosene to the aeration tank is recommended to prevent it.[19] The settling tank should be studied for short circuiting.

The Dorr-Mineralisator has proven reliable but a periodic check of the above is necessary.

In case some changes occur in the process chemical and biological tests of the waste water should be carried to determine the effect of these changes on the plant.

Structural Design of Tanks.

The two aeration and settling tanks are designed considering the two aeration tanks as one unit separated by a long centre wall and assuming the settling tank to be one additional unit; although its depth is 0.75 m less than the aeration tanks, with the exception of the hopper which is of the same depth as the aeration tanks. The design is based on an accurate paper presented by Portland Cement Association[50] that gives coefficients of moment and shear for the various sections of the rectangular tanks. The paper assumes that in rectangular tanks the most accurate situation of fixity results by considering the bottom of the walls hinged and the top free.

Using the same nomeclature as that of the paper, and referring to the diagram presented in the Table V.2 : $a = 2.5$ m, $b = 8.00$ m, $c = 3.00$ m and $b/a = 3.1$, $c/a = 1.2$. Moment, M = coefficient x wa^3; and shear, S = coefficient x wa^2 where w is 1.0 ton/m^2 per m. run, $w.a^3 = 1.0\ (2.5)^3 = 16.5$ ton. m. $wa^2 = 1.0\ (2.5)^2 =$ 6.25 tons.

Table V.3 includes a summary of the coefficients that require investigations as far as the design is concerned.

A study of the mentioned table indicates that the maximum horizontal moment occurs at the top corner of the centre wall and is equal to $M_y = -0.147wa^3$ or $M_y = -0.147 \times 16.5 = -2.42$ ton-m.

$$d = \frac{M}{Kb} = \frac{2.42 \times 1000 \times 100}{12.6 \times 100} = 14 \text{ cm}$$

considering 3 cm cover the thickness is 17 cm; assume 20 cm thickness.

Since the maximum horizontal moment in centre wall is higher than any other horizontal moment a depth of section of 16 cm is taken for all the tanks with a resulting uniform thickness of 20 cm.

Checking for shear, using figure 2 in the PCA paper,

$$\begin{aligned}\text{Maximum shear} &= \text{maximum coefficient x } wa^2. \\ &= 0.42 \times 6.25 = 4.06 \\ &= 2.61 \text{ tons per m.}\end{aligned}$$

$$\text{d required for shear} = \frac{V}{\frac{7}{8} \times vb} = \frac{2.61 \times 1000}{\frac{7}{8} \times 3.5 \times 100} = 10.2 \text{ cm.}$$

and hence d for moment governs.

Disregarding axial tension in the wall, the maximum steel area extending horizontally around the corner is $As = \frac{M}{f_s jd} = \frac{2420 \times 100}{1200 \times 0.86 \times 16} = 14.9$ sq.cm. Considering axial tension due to shear in the long wall and using figure, 2; N is found to be $0.17\ wa^2 = 0.17 \times 6.25 = 1.06$ tons/M. The eccentricity about tensile steel is $e = -100 \frac{M}{N} - d'$, where $d' = \frac{d\text{-cover}}{2}$

$$\text{or} \quad e = \frac{100 \times 2610}{1,060} - (16 - \frac{3}{2}) = 2.15$$

$$= 2.15 \times 100 = 215 \text{ cm.}$$

$$\text{or} \quad E = e = \frac{2.15}{100} \text{ M}$$

$$NE = 1.06 \times 2.15 = 2.28 \text{ ton-m}$$

$$F = bd^2 = 100 \times 256 = 25600 \text{ cm}^3$$

$$KF = \frac{12.8 \times 25600}{1000 \times 100} = 3.30 \text{ ton-m}$$

Since KF is greater than NE, no compressive steel is needed and the compressive concrete stress is less than the allowable.

$$\text{Now, } As = \frac{NE}{f_s jdi} \text{ where } i = \frac{e}{e-jd} = \frac{2.15}{2.15 - 0.86\ (16)}$$

$$\text{or} \quad i = \frac{2.15}{2.02} = 1.06 \text{ m.}$$

$$As = \frac{2.28}{0.86 \times 1.2 \times 16 \times 1.06} = 12.76 \text{ cm}^2$$ (less than 14.9 sq.cm).

Hence the effect of axial tension does not govern.

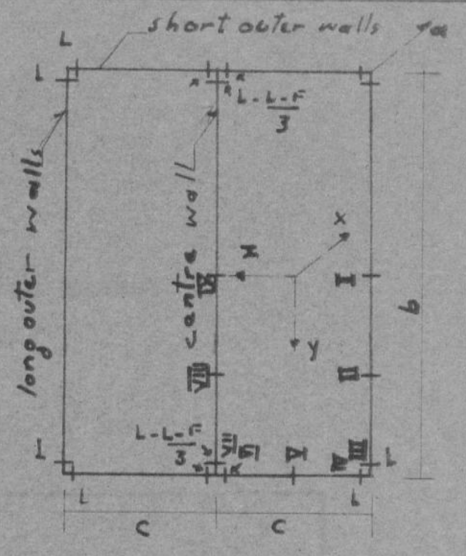
Table V.3 presents calculations of critical moments: Mx, M_y, M_z and the required area of steel A_s (A_x, A_y, A_z) assuming

Table V.

LONG OUTER WALL

L-Coeficients from table V for $\frac{b}{a}=3$, $\frac{c}{a}=1.20$

$\frac{x}{a}$	$y=b/2$		$y=b/4$		$y=0$	
	M_x	M_y	M_x	M_y	M_x	M_y
0	0	-.122	0	+.045	0	+.078
1/4	-.022	-.111	+.019	+.041	+.030	+.067
1/2	-.019	-.095	+.038	+.035	+.050	+.054
3/4	-.014	-.068	+.038	+.023	+.047	+.032



SHORT OUTER WALLS

$\frac{x}{a}$	L-Coeficients from table V for $\frac{b}{a}=3$, $\frac{c}{a}=1.2$						F-coef. from table II for $\frac{b}{a}=1.2$		$L-\frac{L-F}{3}$	
	$Z=c/2$		$Z=c/4$		$Z=0$		$Z=c/2$ (at centre wall)			
	M_x	M_z	M_x	M_z	M_x	M_z	M_x	M_z	M_x	M_z
0	0	-.122	0	-.052	0	-.031	0	-.034	0	-.092
1/4	-.022	-.111	-.011	-.039	-.004	-.018	-.008	-.042	-.017	-.088
1/2	-.019	-.095	-.000	-.022	+.008	-.005	-.010	-.048	-.016	-.080
3/4	-.014	-.068	+.008	-.006	+.016	+.001	-.009	-.044	-.012	-.062

CENTRE WALL

$\frac{x}{a}$	L-coeficients from table V for $\frac{b}{a}=2.5$, $\frac{c}{a}=1.2$						F-coef. from table II for $b/a=2.5$		$L-\frac{L-F}{3}$	
	$y=0$		$y=b/4$		$y=b/2$					
	M_x	M_y	M_x	M_y	M_x	M_y	M_x	M_y	M_x	M_y
0	0	+.078	0	+.045	0	-.122	0	-.196	0	-.147
1/4	+.030	+.067	+.019	+.041	-.022	-.111	-.034	-.170	-.026	-.131
1/2	+.050	+.054	+.038	+.035	-.019	-.095	-.027	-.137	-.022	-.109
3/4	+.047	+.032	+.038	+.023	-.014	-.068	-.017	-.087	-.015	-.071

minus sign indicates tension on loaded side.

MOMENT COEFICIENTS IN TANK WALLS.

TABLE V.3.b

Coefficients and Moment Calculations for Tanks.

(b) Short Outer Wall.

SECTION IV

depth	coefficient (x)	coefficient (z)	M_x	M_z	A_x	A_z
ratio from top			ton-m	ton-m	sq.cm	sq.cm
0	0					
$\frac{1}{4}$	-.022	-.122	0	-2.02	0	-12.80
$\frac{1}{2}$	-.019	-.111	-0.36	-1.80	-2.27	-11.30
$\frac{3}{4}$			-0.31		-1.97	
SECTION V						
0	0	-.031	0	-0.51	0	-3.22
$\frac{1}{4}$	-.004	-018	-0.07	-0.30	-.044	-1.90
$\frac{1}{2}$	-.008		-0.14		-0.88	
$\frac{3}{4}$	-.016		-0.28		-1.76	
SECTION VI						
0	0	-.092	0	-1.52	0	-9.60
$\frac{1}{4}$	-.017	-.088	-0.28	-1.45	-1.78	-9.20
$\frac{1}{2}$	-.016		-0.26		-1.65	
$\frac{3}{4}$						

TABLE V.3.c

Coefficients and Moment Calculations for Tanks.

(c) Long Centre Wall.

SECTION VII

depth	coeffi- cient (y)	coeffi- cient (x)	M_x	A_y	M_x	A_y
ratio from top			ton-m	ton-m	sq.cm	sq.cm
0	0	-.147	0	-2.42	0	-15.40
$\frac{1}{4}$	-.026	-.131	-.43	-2.16	-2.73	-13.60
$\frac{1}{2}$	-,022	-.109	-0.36	-1.80	-2.27	-11.4
$\frac{3}{4}$						
SECTION VIII						
0	0	-045	0	-.074	0	-4.70
$\frac{1}{4}$	-.019	-.041	-0.31	-0.66	-1.97	-4.15
$\frac{1}{2}$	-.038		-0.63		-4.00	
$\frac{3}{4}$	-.038		-0.63		-4.00	
SECTION IX						
0	0	-.078	0	-1.30	0	-8.25
$\frac{1}{4}$	-.030	-.067	-0.50	-1.06	-3.14	-7.1
$\frac{1}{2}$	-.050		-0.83		-5.25	
$\frac{3}{4}$	-.047		-0.71		-4.50	

CHAPTER SIX

COST ESTIMATE

The cost estimate presented here does not include any cost incurred in expanding the processing procedure for the production of 3000 birds per day. A cost estimate of any engineering project is the major item that would make the project economically feasible or deem it as economically unsound.

The cost estimate of the treatment plant for the waste waters from Shuman's Poultry Processing Plant is divided into initial cost and operating cost. The estimates of cost is done on average normal unit prices that might vary with many factors including type of item, the time and the place. In any case, such a cost estimate should give an indication of the expected funds needed. The Dorr-Mineralisator price is given in lumpsum for all the included different parts together, as given by Dorr-Oliver. It is a patented design that is the property of the Dorr-Company; and is sold out as a whole unit.

A. INITIAL COST.

The details of all the items are shown in the attached drawings

Item 1. Concrete work involved in all the plant.

(i) Reinforced concrete in cubic meters:

	Part	Unit price L.L.	Total amount m3	Total price L.L.
(a)	Screen pit	150		
	base 1x1.40x1.00x0.20		0.28	
	walls, 2x1.40x1.50x0.20		0.84	
	walls, 2x1.00x1.50x0.20		0.60	
			1.72	258.00

	Part	Unit Price L.L.	Total amount m3	Total Price L.L.
(b)	<u>Aeration tanks (two)</u>	150		
	long walls, 3x8.00x2.50 x 0.20		12.00	
	short walls, 4x3.00x2.50x0.20		6.00	
	base, 1x8.40x6.60x0.20		11.09	
			29.09	4363.50
(c)	<u>Settling tank</u>	150		
	long wall, 1x8.00x1.75x0.20		2.80	
	short shallow wall, 1x3.40x1.75x0.20		1.19	
	short deep wall, 1x3.40x2.50x0.20		1.70	
	average of base, 1x8.00x3.20x0.20 + 2x0.50 x3.00x0.20		5.72	
			11.81	1771.50
(d)	<u>Screw lift</u>	150		
	equivalent section x horizontal length, 0.75 x 6.40		4.80	
			4.80	720.00
(e)	<u>Effluent distribution box</u>	150		
	walls, 2 x 1.00 x 0.85		1.70	
	walls, 2 x 1.40 x 0.85 1 x 1.40 x 1.40		2.38 1.96	
			6.04	906.00
	Grand Total of R.C.		53.46	8019.00
(ii)	<u>Plain concrete in cubic meters</u>			
	Drying beds	80		
	wall, 3 x 3.80 x 1.00 x 0.20		2.88	
	wall, 2 x 2.50 x 1.00 x 0.20		1.00	
			3.88	310.40
	TOTAL OF ITEM 1			8329.40

Item 2. The Dorr Mineralisator including:

Part	Lumpsum price L.L.
screens,	
vitrified pipe,	
screw lift pump,	
motor for screw lift pump, 1½ Hp,	
brush aerator,	
motor with tex rope transmission for brush aerator, 3 Hp,	
wooden flase bottom for the aeration tank,	
turnable level control pipes,	
steel guiding vanes,	
steel guiding body,	
chain scraper,	
motor for chain scraper, ½ Hp,	
switch panel and its wirings,	
telescopic pipe for return sludge,	
effluent launder,	
connections,	
Total of Item 2	35,000.00

Item 3. Earth works:

	Total Price L.L.
Cut and fill with necessary compaction (lumpsum)	
Total of Item 3	2500.00

Item 4. Drying beds including:

Gravel	
Sand	
Drains	
Pipes	
Connection	
Distribution	
Valves and miscellaneous (lump sum)	
Total of Item 4	500.00

			Totat Price L.L.
Item	5.	Pipes needed for irrigation Meters length: 300 m @ L.L. 6/m.L.(average)	1800.00
		Total of Items 1,2,3,4 and 5	48,129.40
	6.	Miscellaneious Contingencies, Interest on money and unforeseen: 15%	7219.60
		GRAND TOTAL	55,349.00

B. OPERATIONAL COST

The basic relationship in operational cost estimate is the variation in cost versus capacity. Since the plant operates at the same capacity each day, the daily operating cost is basically the same. The operational cost is estimated on annual basis considering 52 weeks, 6 days a week:-

1. Man-hour requirement

It was stated that in small plants an average of 4.2 man-hour per week were needed. It will be assumed that one man working two hours a day will be able to operate the plant successfully. This operation procedure is equivalent to 12 man-hour a week which is more in compliance with the average man-hour requirement of 12.7 given by 52 plants surveyed in the United States.

The operator will be probably working at the Shuman's poultry plant as well; and hence the induced operating cost, is 12 x 3 = LL.36 a week or 52 x 36 = L.L. 1880 per annum.

2. Power requirement per annum in Kw-hr.

		Unit Price L.L.	Total amount Kw-hr	Total Price L.L.
a)	Hp motor of brush working five hours during processing 3 x 0.746 x 5 x 6 x 52	0.10	3500	

		Unit Price L.L.	Total amount Kw-hr	Total Price L.L.
b)	Same motor working for 19 hours for plain aeration in cycles of one houre operation and 30 min.rest $\frac{19}{1.5} \times 3 \times 0.746 \times 6 \times 52$		9000	
c)	Motor for screw lift pump $1\frac{1}{2} \times 0.746 \times 5 \times 6 \times 52$		1750	
d)	Motor for scraper $\frac{1}{2} \times 0.746 \times 6 \times 52 \times 5$		583	
	Total		24,833	2483.00
e)	Miscellaneious, maintenance, contingencies and interest on operating cost 25%			617.00
	GRAND TOTAL			4980.00

C. TOTAL COST VS.REVENUES

To get a more accurate picture of the economic feasibility of the treatment plant, aside from the sanitary need for such a plant, the approximate revenues of the processing plant should be considered.

The proposed processing plant will produce 3000 chickens per day, six days a week, Assuming the average profit per chicken is L.L. 1, considering losses, the annual net income of the farm would be:-

52 x 6 x 3000 x 1 = L.L. 936,000 per annum.

It is rather difficult to assess the little annual income due to the agricultural use of the treated waste waters, and hence it will be neglected for the purposes of this calculation:-

Cost of proposed treatment plant	L.L. 55,400
Annual cost of plant based on an operation life of 20 years	L.L. 2,770
Annual operational cost	L.L. 4,980
Total annual costs	L.L. 7,750
Cost of treatment to revenues calculated as a percentage	0.8%

The initial and the operating costs therefore, comprise only a small percentage of the annual revenue.

In addition, the main item, the Dorr-Mineralisator is reported by Dorr-Oliver to be the cheapest treatment equipment offered for the range of capacities employed here. The next in cost might be the Dorr-clarigestor with a chemical feeder of $FeCl_3$ which costs L.L. 10,000 over and above the Mineralisator. Its reported efficiency is about 30% less.

The treatment plant complying well within the requirements of sanitary as well as economic aspects is conclusively a feasible engineering project.

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