SAMPLE - DO NOT REMOVE

Papers Presented at Fifth Ontario INDUSTRIAL WASTE Conference

MAY 25th, 26th, 27th, 28th
1958

SPONSORED BY
THE WATER AND POLLUTION ADVISORY COMMITTEE
OF THE
ONTARIO WATER RESOURCES COMMISSION

AT
Delawana Inn
Honey Harbour, Ontario

INDEX

FIFTH ONTARIO INDUSTRIAL WASTE CONFERENCE

SPONSORED BY

THE WATER AND POLLUTION ADVISORY COMMITTEE

OF THE ONTARIO WATER RESOURCES COMMISSION

The Ontario Water Resources Commission is pleased to make available this set of papers presented at the Fifth Ontario Industrial Waste Conference held at Delawana Inn, Honey Harbour, Ontario on May 25,26,27,28, 1958. In doing so, it is hoped that the dissemination of this information will have wide benefits and will result in better methods of industrial waste disposal.

The papers given at this Conference are printed in this brochure in the order in which they were given. A list of those persons who attended the conference is also contained in the brochure for reference purposes. These papers contain valuable information given by persons who are recognized leaders in their fields. A careful study of the papers is recommended for all who are concerned with this problem.

Industrial wastes in the Province of Ontario constitute an important factor in stream sanitation. They must be considered in conjunction with domestic sewage and other wastes which may impair the quality of the receiving watercourses. The fact that Ontario is growing industrially at a rapid pace creates additional problems in this field. The objective of the Water Resources Commission is to make it possible for the operation of these various industrial plants in such a way that the quality of the streams may be maintained for the many uses which are normally required of watercourses. As the Province grows, this problem becomes more acute. It is necessary to plan in advance and to make certain that all wastes are adequately treated before they are discharged.

The industrial waste problem is one of great magnitude not only because of the complexity of the wastes themselves, but also through the cost involved in providing treatment. It thus becomes all important that effective measures be devised which will bring satisfactory results, and at the same time the most economical procedures. Measures to be adopted must be co-ordinated with the ever changing composition of industrial wastes; One of the best ways to meet this challenge is to hold conferences, such as this one, where there can be a free exchange of information with others.

The Water and Pollution Advisory Committee has been responsible for the preparation of the programme of this Conference. The Committee members come from different departments of Government, and accordingly they are interested in all types of pollution. By acting together in this way there is a co-ordination of efforts and interests, and a broader approach to this complex problem than would otherwise be the case. Existing legislation in Ontario makes it possible to deal with all forms of wastes which may in any way impair the quality of the receiving stream irrespective of the purpose that stream may serve as its primary function.

The Water and Pollution Advisory Committee is grateful to all who have contributed, in any way to this programme of papers and discussions. The interest manifest in these conferences is increasing, a situation which reflects the quality of the papers presented, as well as the general concern in this overall problem. The Ontario. Water Resources Commission is glad to be of service in this way and will welcome any suggestions for attacking the problem more effectively.

For further information write to:

The Water and Pollution Advisory Committee,
Ontario Water Resources Commission,
East Block, Parliament Buildings,
TORONTO, Ontario.

A LABORATORY STUDY OF OZONE TREATMENT OF REFINERY PHENOLIC WASTES

- by -

M. L. Peppler
G. R. H. Fern

Imperial Oil Limited
Sarnia, Ontario

Abstract

Biological Oxidation has found considerable favour as a method of phenol destruction in Refinery Wastes. It has been known for a long time that ozone would destroy phenols effectively, but the cost of ozone treatment appeared to be prohibitive. More recently it appeared that ozone might be becoming competitive on a cost basis and therefore it was decided to investigate, on a laboratory scale, the feasibility of ozone as a method of treatment for Refinery Phenolic Wastes.

The effect of pH and stripping on the various types of waste were studied. The pH was found to have little effect on the ozonation of Treating Plant Wash Water and Cat Cracker Condensate both of which are naturally alkaline. However, for a solution of pure phenol and distilled water the pH was significant in the range 5.7 to 12.3. It would appear from this work that the optimum pH was about 12.

Sulphides have an ozone demand and must be removed if present in appreciable concentrations as in cat cracker condensate. Hence, stripping would probably be required in a commercial ozone treatment plant.

Ozonation may have a slight economic advantage over Biological Oxidation for wastes which do not contain significant amounts of oxidizable impurities, i.e. sulphides, but it is much more expensive if the waste must be stripped prior to ozone treatment.

Ozone treatment produces a very high quality effluent but based on this investigation, it is extremely doubtful that it would replace Biological Oxidation of Refinery Wastes due to economic considerations.

INTRODUCTION

Biological Oxidation has met with considerable success in the destruction of phenolic compounds in refinery waste waters. Chemical oxidation employing ozone, chlorine dioxide, etc. is an alternative method which has not been economically attractive in the past. Aside from the standpoint of cost, ozone would be an excellent method for phenol reductions; the treated water is of very high quality and contains no objectionable by-products, the reduction product of ozone being oxygen. Recent developments in ozone technology led to the belief that ozone treatment might have become competitive with Biological Oxidation.

It was decided, therefore, to conduct a laboratory investigation into the feasibility of such a process including a study of the ozone demand and the various factors that influence the ozone demand of refinery phenolic waste. The ozone demand is defined as the number of pounds of ozone required to completely oxidize one pound of phenol. The variables considered to be most important were pH and oxidizable materials other than phenols.

THEORETICAL

The theoretical ozone requirement for phenol destruction is three moles of ozone per mole of phenol. This corresponds to a ratio of about 1.5 pounds of ozone per pound of phenol. At a high pH, ozonation of phenol proceeds in preference to competing oxidation reactions, but the stability of ozone in water solution decreases with increasing pH. The optimum pH for a solution of pure phensol and water is 12. However, refinery waste waters contain other substances which are also ozone consumers. The chief competing reaction is the oxidation of sulphides to sulphites and sulphates.

EXPERIMENTAL

A. Apparatus

Reactions were carried out in a glass reactor having a capacity of about five litres. This is illustrated in Figure I. It consisted basically of a vertical glass tower having four fritted glass diffusers at the bottom from which a mixture of ozone and oxygen were supplied to the water being treated. A pump circulated water from the lower part of the reactor through a cooling condenser and back to the reactor above the surface of the water. The pump had stainless steel parts and all connecting tubing was of stainless steel, glass or tygon.

Ozone was supplied to the reactor from a Welsback T-23 laboratory ozonator. Oxygen was fed to the ozonator from an oxygen cylinder (air may also be used). An electrical discharge in the ozonator converted a portion of the oxygen feed to ozone. It is important that the input to the ozonator be dry and a calcium chloride drying bottle was connected in the line for this purpose.

B. Analytical Procedure

1. Determination of Ozone

Ozone reacts with potassium iodide to liberate iodine, according to the equation:

$$2KI + H_2O + O_3 \rightarrow I_2 + 2KOH + O_2$$

The liberated iodine can then be titrated with standard sodium thiosulphate solution. Reagents used were as follows:

2% KI solution
1 Molar H_2SO_4 solution
0.1 Normal $Na_2S_2O_3$ solution

The ozone and oxygen mixture was bubbled through 400 millilitres of KI solution in a 500 ml gas washing bottle for one minute. The solution was then transferred quantitatively to a one litre beaker, acidified with 10 ml of H_2SO_4 solution and titrated with standard $Na_2S_2O_3$ solution using Thyodene indicator just before the solution cleared.

The ozone dosage in grams per hour may be calculated from the following formula:

$$O_3 = \frac{T \times 0.024 \times N \times 60}{t}$$

Where O_3 = Ozone in grams per hour
T = titration in ml of $Na_2S_2O_3$ solution
N = normality of $Na_2S_2O_3$ solution
t = gas bubbling time in minutes

When $N = 0.100$ and t is one minute, the formula may be reduced to

$$O_3 \text{ (gm/hr)} = 0.144\ T$$

2. Determination of Phenols

Phenol concentrations were determined by the Gibbs method.

3. Determination of Sulphur

The sulphur content of water samples was determined potentiometrically. In this method a silver-silver sulphide electrode and a glass electrode were used. The titrating medium consisted of 160 grams of NaOH and 40 millilitres of ammonium hydroxide diluted to four litres. The titrant was 0.01 normal alcoholic silver nitrate.

C. Procedure

The ozonator was adjusted to give a flow rate of 0.04 cu. ft./min. to the reactor. The ozone content was determined by the potassium iodide method at the beginning of each run and after forty-five minutes. Ozone dosage was about three grams per hour at this rate of flow. A gallon of the test was introduced into the reactor through a three-way stop-cock upstream of the pump. Ozone feed was started and 150 ml samples of water were removed for analysis at timed intervals over the course of an hour and a half. Ozone dosage was calculated in parts ozone per million parts water, correcting for the change in volume after each sample was taken.

RESULTS

Table 2 summarizes the data for the various runs made. The data for each is presented in Figures 2 to 9

During each run there was a considerable drop in pH. Since the optimum pH, according to Niegowski (2) is in the neighbourhood of 12, this may cause a corresponding increase in ozone demand as the treating progresses.

1. Pure Phenol and Water

Figure II illustrates the data for the ideal case of pure plant phenol and distilled water, with no competing ozone consumers. In order to investigate the effect of pH on ozone demand, one gallon of a sample was treated directly while a second was buffered up to a pH of about 12 with sodium hydroxide and disodium phosphate. The effect of pH on the efficiency of phenol destruction was marked. The sample having the natural low pH of a phenol solution (5.7) required 2.4 pounds of ozone per pound of phenol, while the samples at pH 12.3 required only 1.6 pounds ozone. The latter corresponds to a mole ratio of slightly more than three to one, the theoratical ratio.

2. Effect of Sulphides

Figure III illustrates the data for a sample of phenolic waste water containing a high concentration of sulphides. The sample used was unstripped cat cracker condensate water with a pH of 8.5, containing 1450 ppm sulphur as H_2S, 200 ppm sulphur as mercaptans and 550 ppm of phenols.

It is apparent from the graph that the oxidation of sulphides to sulphites and sulphates proceeds in preference to other reactions, phenols not being attacked until sulphides are oxidized. High sulphides would therefore give the water an extremely high ozone demand.

3. Central Treating Plant Wash Water

Figure IV shows the effect of pH on the ozone demand of treating plant wash water. One large sample of wash water was adjusted to different pH values by addition of NaOH pellets.

It can be seen from the graph that the variation of pH in the range of 9.0 to 11.7 had little, if any effect on the ozone demand of the water. Within the limits of experimental error, the ozone demand was 3.5 to 4 pounds of ozone per pound of phenol in each case.

Two runs were made to determine the effect of flue gas and steam stripping on the ozone demand of treating plant water. Samples used were the feed and effluent waters from the sour water stripper at the D.S.A. plant. The results of these runs are shown in Figure V. It is apparent from the graph that the total ozone consumption was independent of stripping for these low sulphide waters.

The stripped water, having a lower pH, had a slightly higher ozone demand per pound of phenol, but this was offset by the lowered phenol content. This water was low in sulphide and hence the stripping prior to ozone treatment was not necessary.

4. Cat Cracker Condensate Water

The sulphide situation is different in the case of Cat Cracker condensate which is normally quite high in sulphides. Figure V shows the effect of stripping on the ozone demand of Cat Cracker condensate water. The samples used were feed and effluent water from the Sour Water Stripper at the D. S. A. Plant.

The ozone demand of unstripped Cat Cracker condensate was very large, phenol destruction being almost negligible. The sulphides were being oxidized in preference to ozonation of phenols. The ozone demand of stripped water, however, was down to about five and a half pounds per pound of phenol. The pH of this sample dropped from 7.4 to 2.3

Figure VII shows the effect of pH on unstripped Cat Cracker condensate water. One sample was adjusted to a high pH with NaOH pellets.

Although the ozone demand of the water at pH 11.2 was less than that at pH 8.9, it was extremely high in both cases, due, no doubt, to the high sulphide content.

Figure VIII shows the effect of pH on stripped Cat Cracker condensate water. Part of the sample from the effluent of the stripper was ozonated directly and part raised to a pH of about 12.

In each case the ozone demand was about six pounds of ozone per pound of phenol. The curves differed slightly but the ozone requirement for the reduction of phenol content to one part per million was the same.

Therefore stripping would be required before ozone treatment of Cat Cracker condensate.

5. Biological Oxidation Plant Effluent Water

The effluent of the Biological Oxidation plant also was treated with ozone. This water required 345 ppm of ozone to reduce phenol content from 900 to 60 parts per billion. This corresponds to an ozone demand of about 400 pounds per pound of phenol. Phenol concentration appeared to level off at 60 parts per billion. This is illustrated in Figure IX.

DISCUSSION

It appears that the ozone demand of sour waters from Sarnia refinery would be in the range of 3.5 to 6 pounds per pound of phenol destroyed, depending on the source of the water, and the oxidizable materials other than phenol present in the water. Stripping would still be necessary in water high in sulphides. It would appear that there are interfering substances present in Sarnia refinery effluent which raise ozone demand. The pH dependence exhibited by pure phenol in distilled water did not appear to apply to refinery waste, in which variation of pH, at least in the range above 8, had little or no significant effect. Since refinery phenolic water normally has a pH in the alkaline range, adjusting the pH would not seem to be advisable. The effluent from the Biological Oxidation Plant had a very high ozone demand. In view of this, the use of ozone as a polishing operation following Biological Oxidation would not be economically attractive but might be required if a particularly stringent phenol limit were placed on a refinery effluent.

It is of interest to compare the relative costs of Biological Oxidation and ozone treatment of phenolic refinery wastes. The cost data can be summarized as follows:

	$ per lb. of Phenol Destroyed
1. Steam and Flue Gas Stripping	$ 0.91/lb. of phenol
2. Biological Oxidation (based on the consumption of 800 lb/day of phenol)	$ 0.24/lb. of phenol
3. Ozone at $0.273/lb of Ozone (based on an ozone demand of 3.5 to 6)	$ 0.95-1.65/lb. of phenol

Since it has been found necessary to strip both Treating Plant wash water and Cat Cracker condensate, the total cost of the biological process is $1.15/lb of phenol. Thus ozone may have a slight economic advantage, for the treatment of a waste which does not require sulphide removal but Biological Oxidation has a distinct advantage for wastes which are high in sulphides and require stripping.

CONCLUSIONS

Ozone treatment of refinery phenolic wastes will produce an effluent of very high quality. However, sulphides are oxidized in preference to phenols and result in an extremely high ozone consumption. Therefore in most cases steam and flue gas stripping would be required before ozone treatment which renders Biological Oxidation more attractive economically than ozone treatment.

REFERENCES

1. Long, Louis Jr., The Ozonization Reaction, Chem. Rev. December 1940, p. 437.
2. Niegowski, S.P., Sewage and Industrial Wastes, Oct. 1956, p. 1266
3. Standard Methods for the Examination of Water Sewage and Industrial Wastes Tenth Ed. 1955, American Public Health Association, Inc.
4. Removal of Phenols from Refinery Wastes, Oil in Canada, June 24, 1957, p. 26.

TABLE I

LABORATORY OZONATION OF REFINERY PHENOLIC WASTES

Sample	Initial pH	Final pH	Initial Phenol in ppm	ppm O_3 / ppm Phenol	Remarks
Plant phenol in distilled water					
(1) as is	5.7	2.5	492	2.4:1	
(2) buffered to high pH	12.3	11.8	525	1.6:1	Close to theoretical value of 1.5:1
692 Tank (treating plant wash water) (1)	9.0	8.9	288	= 3.5:1	pH apparently not critical in this range
(2)	10.5	9.2	296	= 3.5:1	
(3)	11.7	9.5	260	= 4:1	
Central treating plant water					Total Ozone consumption identical for the two samples
(1) Unstripped	12.0	7.5	114	4.1	
(2) Stripped	7.9	6.8	85	4.7:1	
Cat Cracker Condensate					
(1) Unstripped	8.9	8.2	200	Very high	
(2) Stripped	7.4	2.3	154	5.5:1	
Cat Cracker Condensate Unstripped					
(1) As is	8.9	8.7	250	Very high	
(2) pH raised	12.6	11.2	250	Very high	
Cat Cracker Condensate Stripped					
(1) As is	7.0	1.8	114	6:1	
(2) pH raised	12.6	9.7	114	6:1	
Biological Plant Effluent	7.6		0.900	400:1	

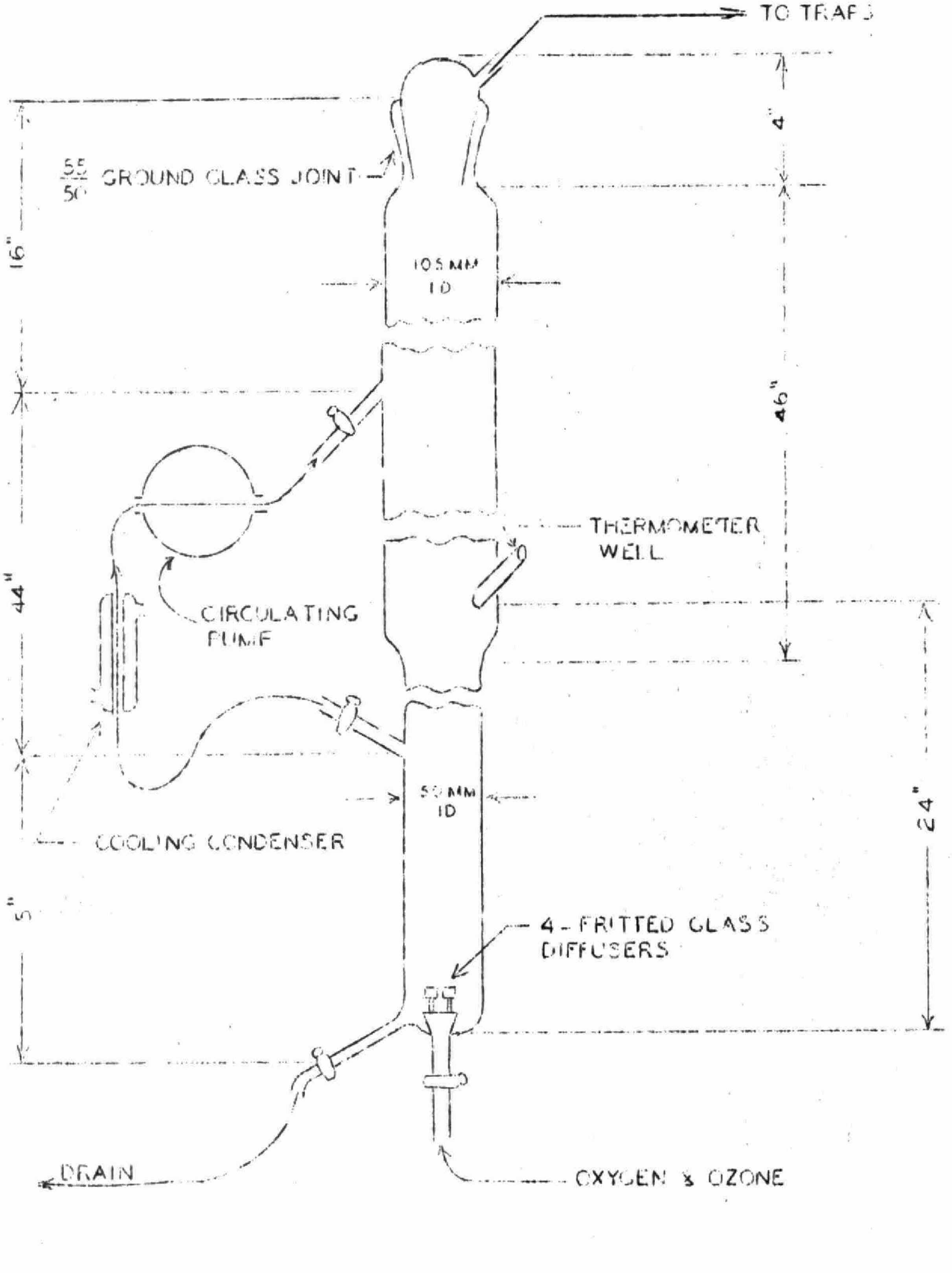


FIGURE I - FIVE LITRE LABORATORY OZONATION REACTOR

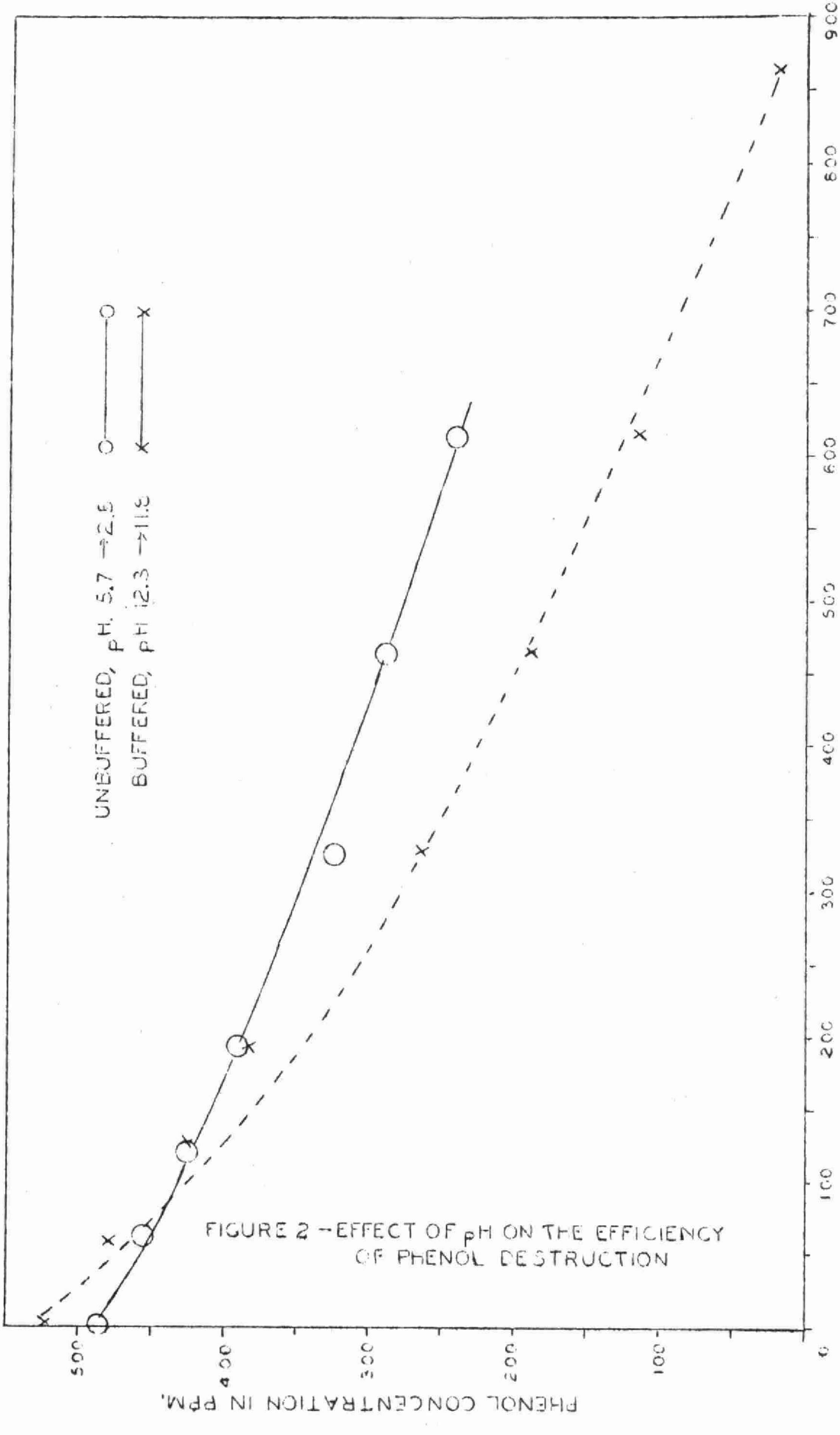


FIGURE 2 – EFFECT OF pH ON THE EFFICIENCY OF PHENOL DESTRUCTION

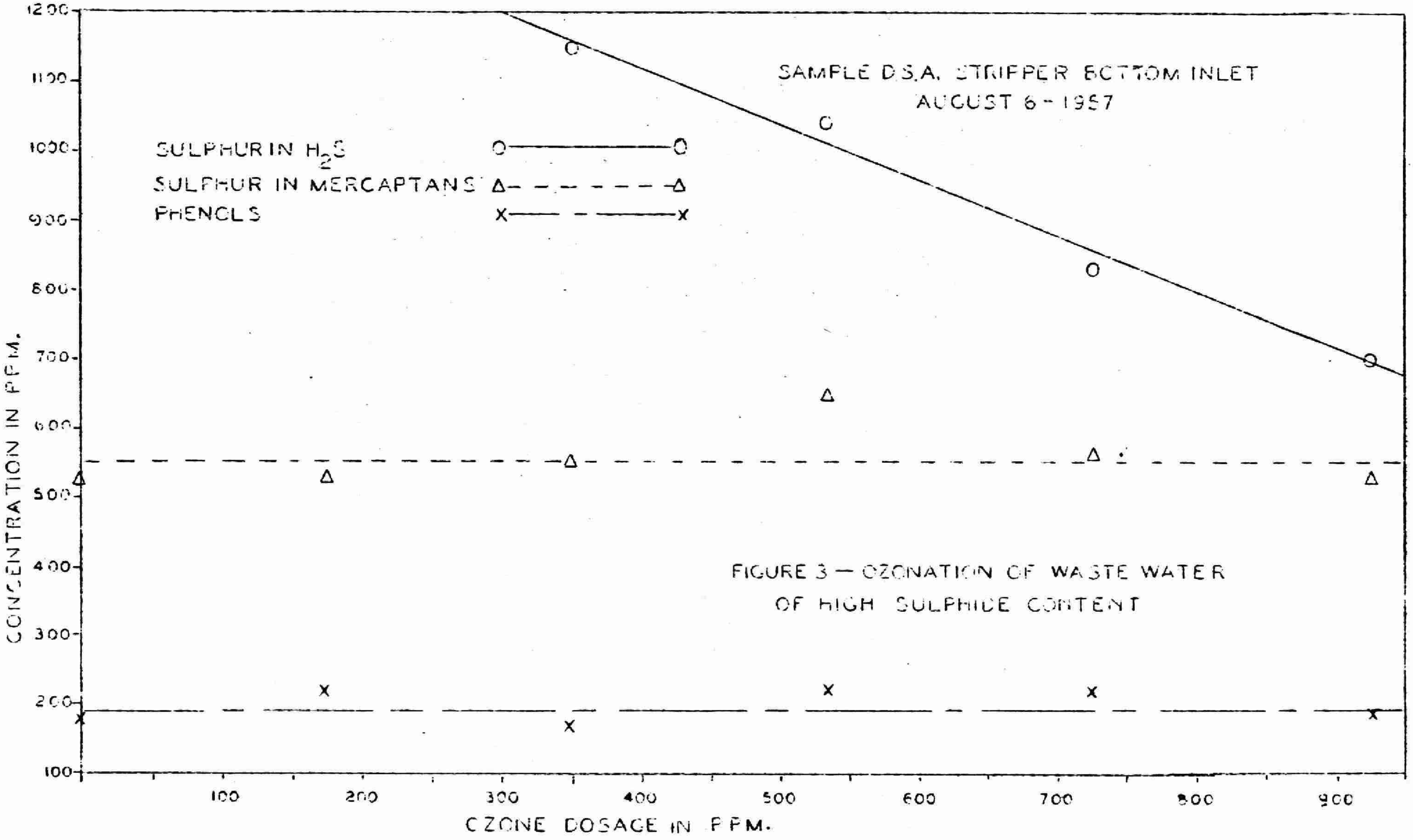


FIGURE 3 — OZONATION OF WASTE WATER OF HIGH SULPHIDE CONTENT

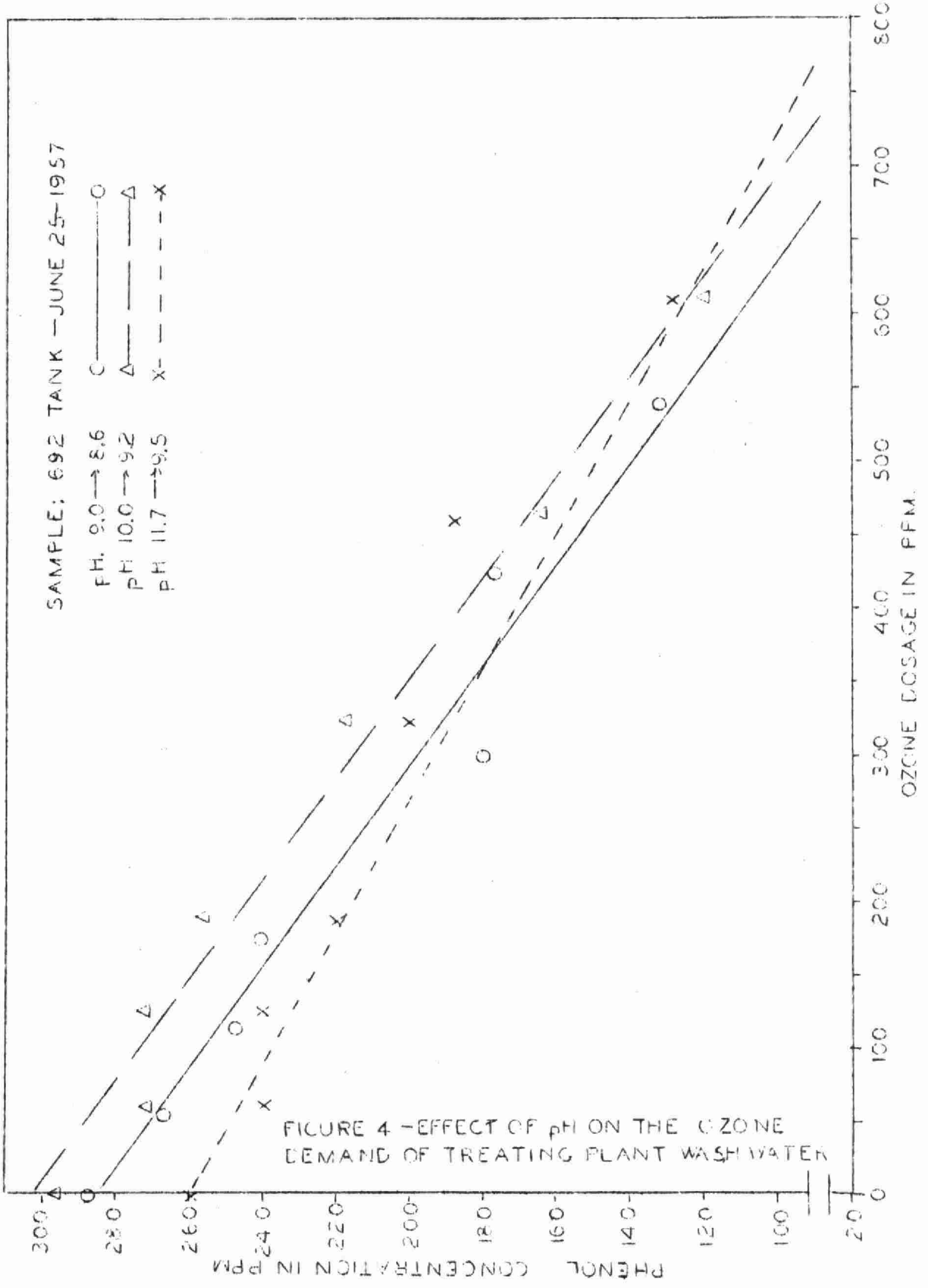


FIGURE 4 - EFFECT OF pH ON THE OZONE DEMAND OF TREATING PLANT WASH WATER

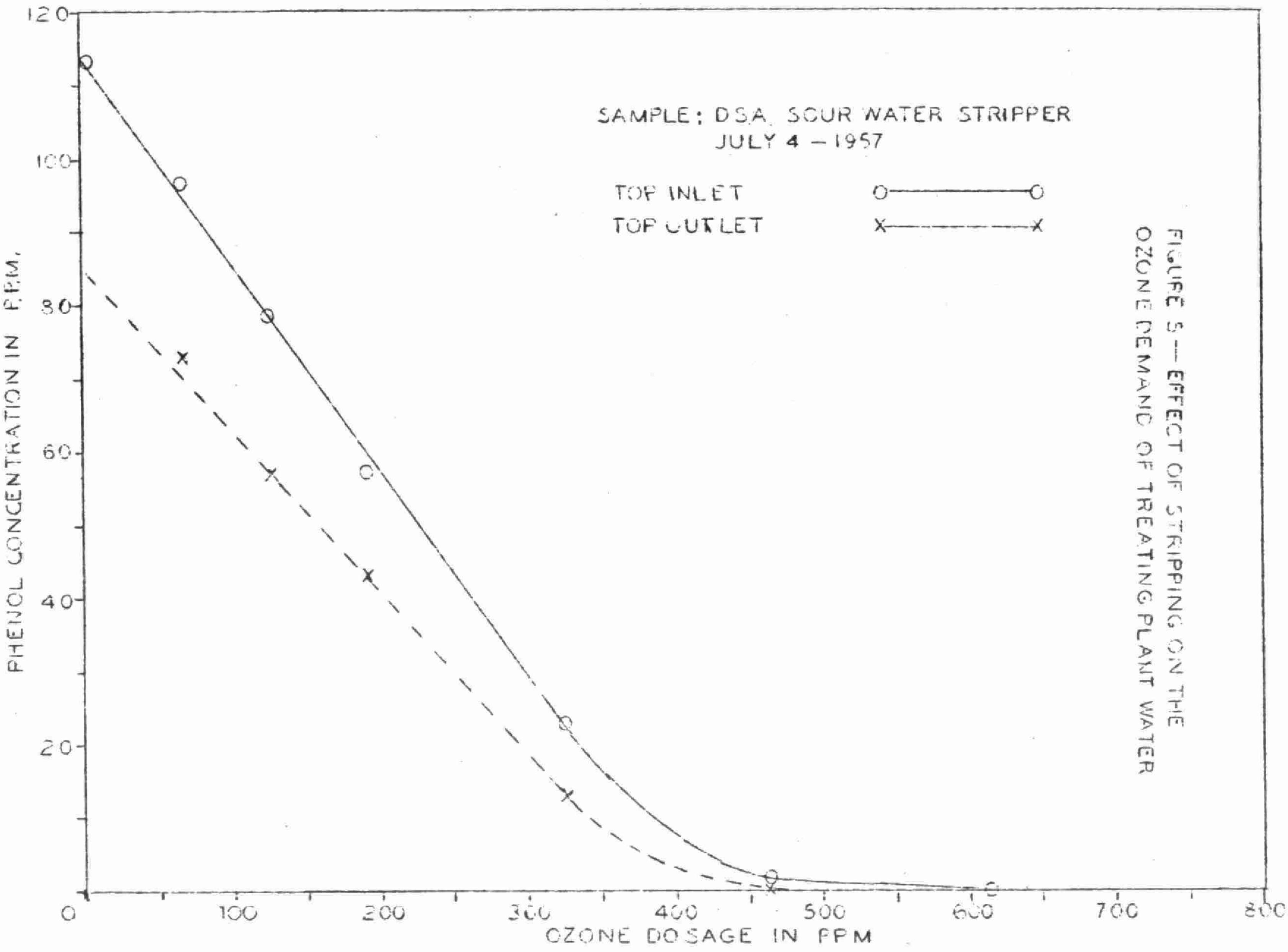


FIGURE 5 — EFFECT OF STRIPPING ON THE OZONE DEMAND OF TREATING PLANT WATER

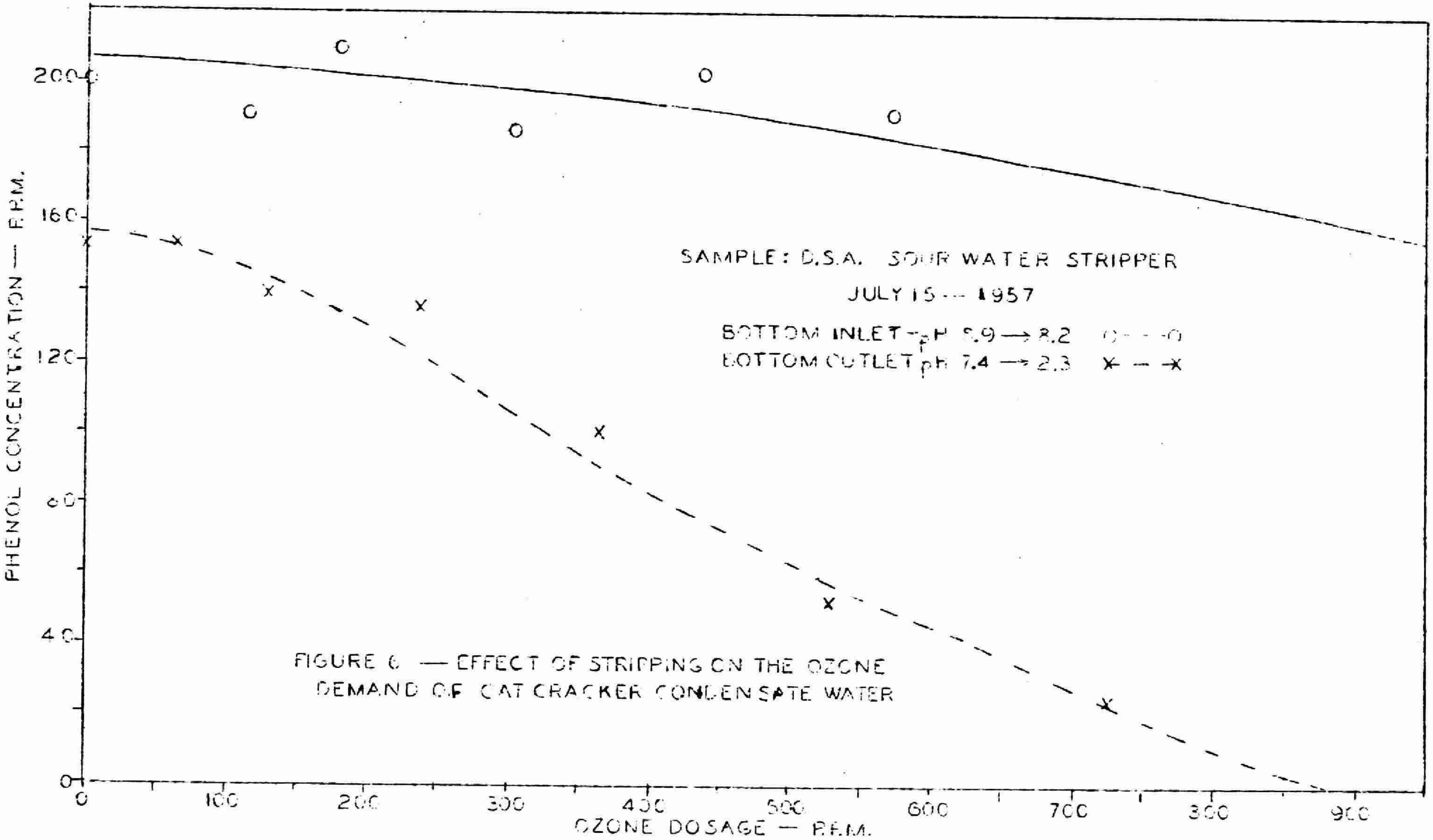


FIGURE 6 — EFFECT OF STRIPPING ON THE OZONE DEMAND OF CAT CRACKER CONDENSATE WATER

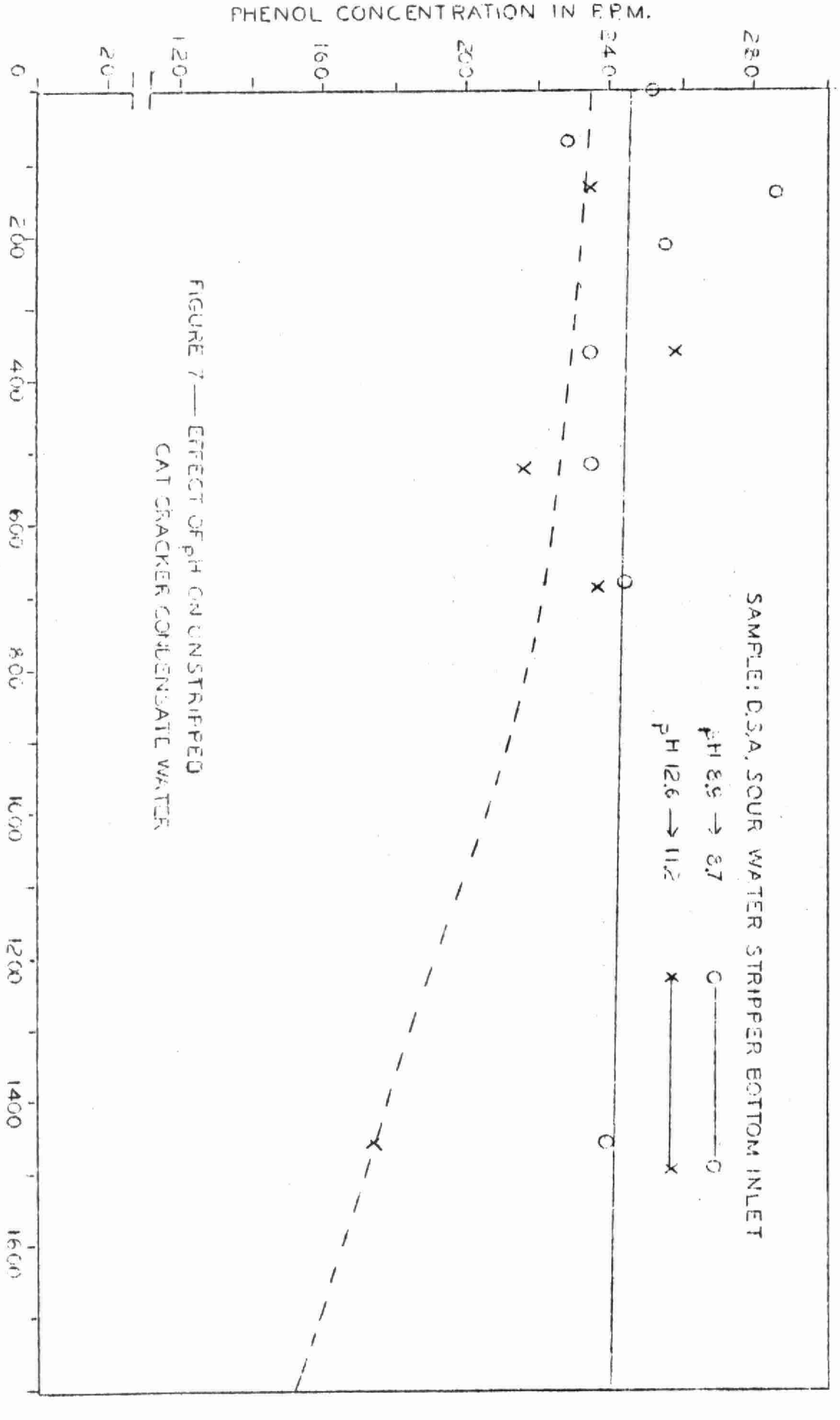


FIGURE 7 — EFFECT OF pH ON UNSTRIPPED CAT CRACKER CONDENSATE WATER

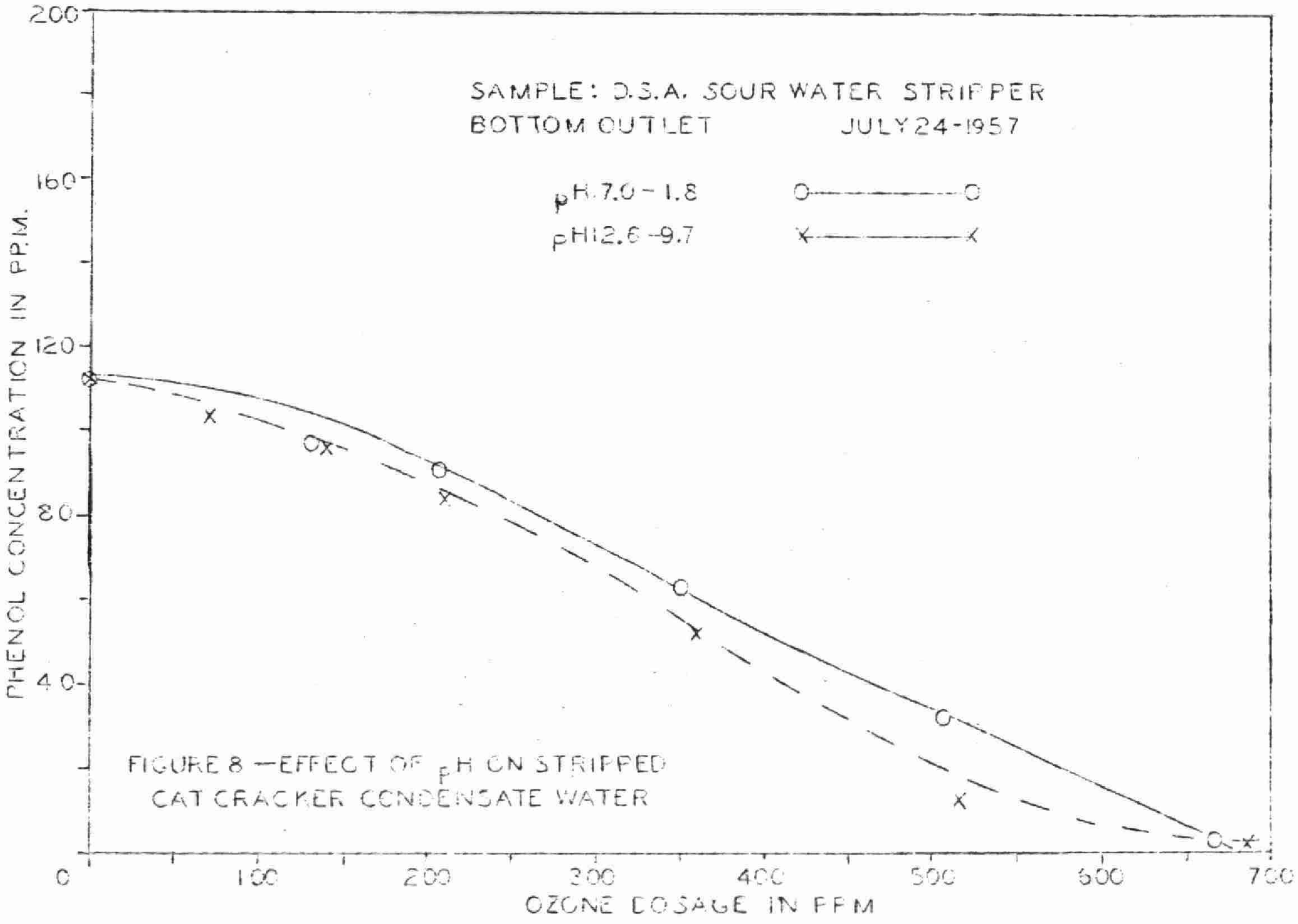


FIGURE 8 —EFFECT OF pH ON STRIPPED CAT CRACKER CONDENSATE WATER

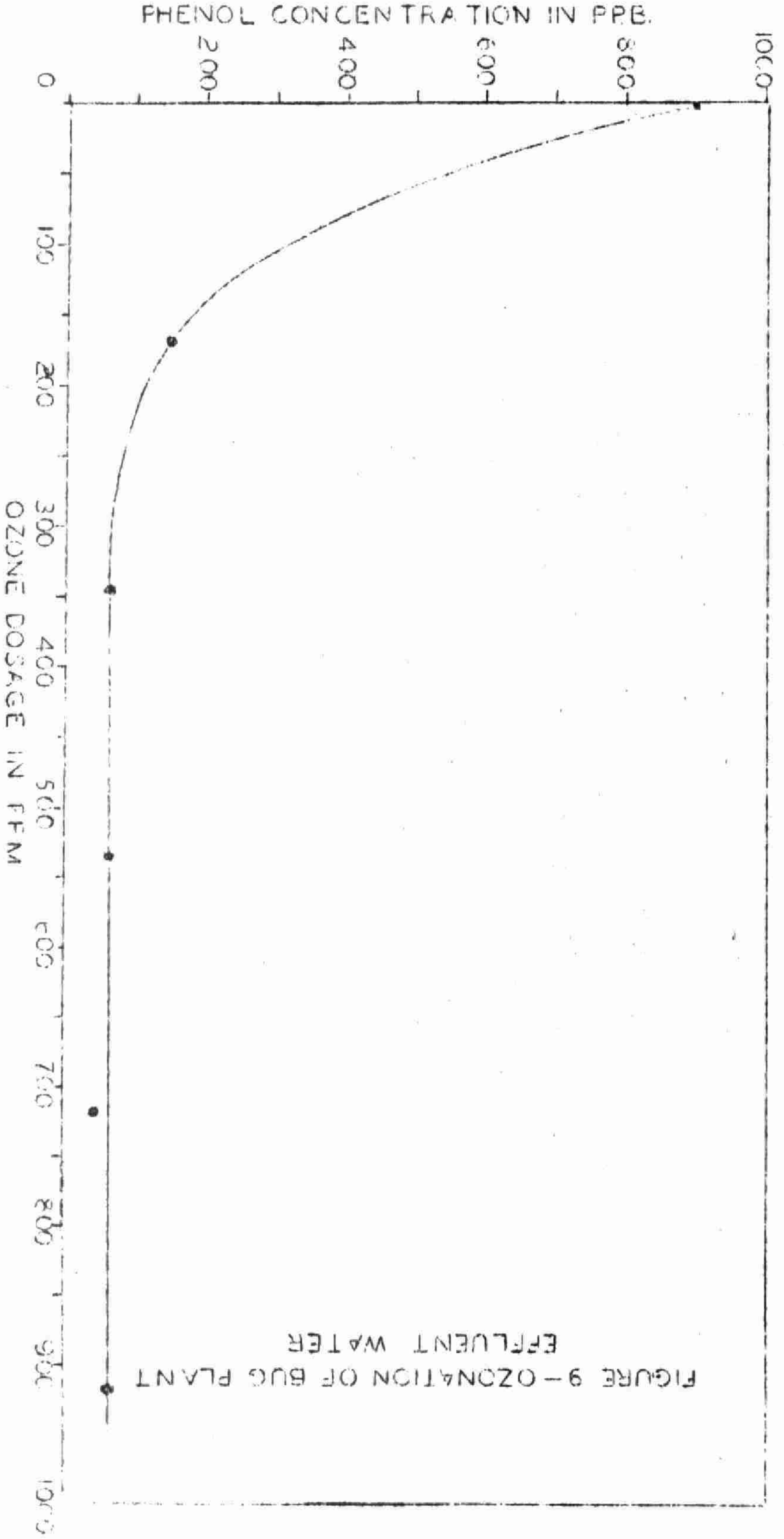


FIGURE 9 — OZONATION OF BUG PLANT EFFLUENT WATER

THE BIOLOGY OF THE ST. CLAIR RIVER

- by -

T. W. BEAK

Consulting Biologist
Amherst Bay
Collins Bay
Kingston, Ontario

The St. Clair River, as most of those present will know, joins Lake Huron to Lake St. Clair, which in turn empties into Lake Erie. It follows that it carries the whole outflow from the Lake Superior, Lake Mighigan and Lake Huron catchments; except that which is diverted elsewhere through canals. It is, therefore, a large river having an estimated average flow of 174,000 c.f.s..

The river forms the boundary between the United States and Canada. On its eastern bank is the industrial town of Sarnia and a number of smaller communities. Sarnia has nine major industrial plants including three oil refineries, three large chemical plants, a tetra-ethyl plant, a fibreglass plant and a plating works. The managements of these plants have formed a joint committee called "The St. Clair River Research Committee" to study air and water pollution in the vicinity of Sarnia. The study described in this paper was sponsored and financed by this committee. I am indebted to it for permission to give this paper. I should like to say that in my opinion the fact that the committee sponsored the work of its own accord and at its own expense and subsequently permitted me to use data from it for this paper speaks highly of the public-spiritedness of its members.

The study described in this paper was undertaken because the St. Clair River Research Committee wanted data on what effect, if any, effluents from industrial plants in the Sarnia district were having on the biology of the St. Clair River. It was undertaken as a voluntary effort on the part of this committee solely for the purpose of collecting data and not because of any pressure or threat from fishery or other interests.

Before going on to consider what has been done so far in this study I should like to digress for a few minutes to explain why a biological rather than a chemical study of the St. Clair River was undertaken.

A considerable amount of chemical work has been carried out in the past on the St. Clair River by the International Commission for Boundary Waters, the Ontario Water Resources Board and the industries themselves. Although chemical analysis is an important tool in water pollution study there are limitations to the data obtained from it. The principal of these are first that it is only possible to obtain data about those chemical substances which are known to be present and for which a suitable analytical method is available and secondly, even when analytical results are obtained they are of optimum value only if the biological or other effects of chemicals present is known. Particularly in a situation like the St. Clair River in which there is a number of industries using a variety of materials no one knows exactly what chemicals might be released with effluent waters, nor all the effects of even the known ones. A direct measurement of biological changes by means of biological surveys and other biological tests is therefore the only practical method of obtaining an overall picture of the effects which industrial activity and domestic pollution is having on the natural waters in the area.

Any large concentration of industry and population is a potential source of pollution. Whatever precautions may be taken, whatever treatment may be given to wastes, there is always some foreign matter which must be disposed of, and ultimately it will find its way to a natural watercourse. Fortunately natural waters, and particularly large rivers like the St. Clair, have an enormous capacity for absorbing foreign matter, utilizing it in one way or another and rendering it harmless. Such foreign matter only becomes pollution in the practical sense when the amount of it exceeds the capacity of the river for absorbtion without undergoing a major biological change. One of the most practical methods of measuring pollution is therefore to measure the change in the biology of the river.

Because applied freshwater biology has in the past been mostly concerned with fishery problems, it is sometimes thought that biological studies of rivers are concerned solely with the effects of pollution on fisheries. This is by no means the case. Fish are but a part of the biological complex of freshwaters. Far less conspicuous and less well known, but at least equal in importance is the large number of animals and plants ranging in size from minute algae to large clams which also live in fresh waters. It is these organisms which are responsible for the self-purification of natural waters. By studying them, and particularly the changes which take place in their species and numbers, it is possible to obtain a measure of pollution in a much wider sense than merely its effect on fisheries. So far I do not know of any biological means of measuring very small quantities of certain taste-producing substances such as phenols, but apart from this biological surveys can and do give a measure of the whole range of the effects of water pollution. Biological methods do not replace chemical analysis, but they supplement it and supply a great deal of information which cannot be obtained by chemical means.

The work so far completed in this study is of a preliminary nature. Some results have been obtained, but they are not sufficiently conclusive to justify publication at this stage. One survey only has been made, the purpose of which was to obtain a reliable measure of the problems involved in making a comprehensive study of the biology of a large river such as the St. Clair. The results of this survey have assisted greatly in drawing up a comprehensive plan. The present paper describes the methods used in the preliminary survey and in interpreting the results and how these results have been used to formulate future plans.

For the benefit of those who are not familar with the use of biological surveys in the study of pollution I shall briefly describe the nature of these studies; I hope those of you to whom this is "old hat" will bear with me.

Almost every aquatic habitat, unless it is grossly polluted, has a community of animals and plants living in it. These vary greatly in size, in density of populations and in species, but these communities of plants and animals are not haphazard in distribution. Their composition is related to the integration of the chemical, physical and biological characteristics of the environment.

Even under natural unpolluted conditions there is enormous variation in these communities. The plants and animals living in a swift mountain stream will be entirely different from those in a large sluggish river and different from those in a lake. There are, however, certain basic similarities in these communities. It is as if each environment consists of a number of "niches". Some of these niches will be found in every type of environment, but according to the chemical and physical conditions of the environment they will be occupied by different species. To illustrate this point, in many environments there will be a "niche" for small, bottom living animals which obtain their living by "grazing" on the minute plants (algae) which adhere to hard surfaces on the bottom. This niche will be found in swift mountain streams, on the stony shores and rapids of larger rivers and the wave-washed shores of lakes. The species occupying the niches will probably vary between these environments, but they will all have certain characteristics in common, e.g., mouth parts capable of scraping the algae from the hard surface, metabolism capable of digesting algae, a means of clinging to hard suffaces and many others.

It follows from this that in making biological studies of rivers and lakes, we have certain frameworks of reference into which to fit our data. The first thing we must do, therefore, is to study the environment and try to form a general picture of the types of environment which are included in the area under study.

An aquatic environment can be divided into the main body of the water, the air/water surface and the bottom. Unless we are to study the whole environment we must first select one of these for study. In the case of a large, fast flowing river where our major aim is the study of the effects of pollution, the bottom and the bottom-living animals are generally found to be the most stable part of the environment and to yield most useful information. This is the reason why these were chosen for study in the case of the St. Clair River.

It was realized in planning the preliminary study that there would probably be differences between the two sides of the river - apart from any pollution effects - and also between the shallower water near the banks and the deeper water near the centre of the river. It was decided therefore, where ever possible to take samples at four points at each station - two respectively near the Canadian and U.S. banks and two in the deeper water approximately one-third way across the river from each side. It was also important to know, if there was any pollution, the extent to which it spread across the river. The islands gave an opportunity to do this. By selecting points on each bank of the river and on two sides of the islands at similar depths, comparison could be made between conditions on the Canadian side of the river, the Canadian and U. S. sides of the islands, and the U. S. side of the river.

The interpretation of the biological results for the study of pollution depends on the known fact that different organisms vary in the degree of their tolerance to various types of pollution. Thus some organisms are very intolerant and will be excluded from an environment by a very small amount of certain substances or a comparatively slight oxygen deficiency. Many organisms can exist in conditions of moderate pollution and a few can thrive even in heavily polluted water. Between the two extremes there are many shades of tolerance.

The first task in a study of this kind is to try to establish the composition of the natural fauna in unpolluted conditions in the river under study. In doing this account must be taken of the different types of habitat in the river, so that differences in animal communities due to natural environmental differences can be distinguished from differences due to pollution. This is very important as differences due to environment can often appear, at least superficially, to be the same as those due to pollution. Having established the types of communities occuring naturally in each type of habitat, these are compared with the communities found in similar habitat below any suspected sources of pollution. If it is found that consistently there is a generalized community above a pollution source and immediately below it only tolerant species (or none at all) are found and that progressing down stream there is a gradual return of the species roughly in the order of their tolerance, until finally at several miles below the pollution source approximately the same community occurs as above it, there is a strong presumption, which with some verification can amount to proof, that pollution is present. This is briefly the way biological surveys are used to measure the presence, the degree and the extent of pollution.

Figure 1 shows a diagram of the St. Clair River from its origin in Lake Huron to Port Lambton where it begins to break up into several channels which flow into Lake St. Clair. It also shows the location of the industrial plants and the sampling stations at which biological samples were taken. It will be seen that Station A was selected to be above any possible pollution from Sarnia, Station B to be below the town of Sarnia but above the major industrial sites. Stations C, D, E, F, G and H are each below the site of a major industry. Stations J, K, L, M and N are selected to give a measure of conditions below the major potential sources of pollution, making special use of islands in the river to compare conditions at various points across the river.

Although the preliminary survey was not regarded as quantitative, it was desired to obtain some idea of the relative abundance of animals. A Peterson dredge was therefore used to obtain all bottom samples. This consists of a grab-like device which is lowered through the water in the open position. On touching bottom a pawl is released. When the dredge is raised the jaws dig into the bottom deposits and enclose an area of approximately one square foot. The closed dredge can be raised to the surface and the contents transferred to a suitable receptacle for further treatment.

At Sarnia the Petersen dredge was operated from a 32 ft. motor boat. As the survey was carried out in November and weather conditions were unfavourable, even this boat was only just large enough to cope with the rough water encountered. The samples were placed in numbered bags and taken back to the pump house of one of the plants where they sieved to separate the living organisms from the bottom material. The organisms and a small amount of material which could not be separated from them were preserved and placed in plastic containers for transport to my laboratory at Kingston.

In the laboratory the organisms were carefully picked out from the other material by hand, sorted into groups, identified and counted. At least two identical samples had been taken at each point. In this way a fairly comprehensive picture was built up of the animal community living on the bottom of the river from a point above Sarnia for about 25 miles downstream.

In view of the fact that only one preliminary survey has so far been carried out and that it is planned to do further, more detailed, quantitative work in this area, I do not intend to give any detailed results at this time. So often I have found that if preliminary results are published, they are quoted by later workers without due reservation with the result that misleading data gets into the literature. I shall confine myself at this time therefore to a few generalizations and to a consideration of the methods which are being used to interpret the data.

Table 1 gives a list of the organisms which have been found in this survey. The groupings will be explained later. This figure shows that some organisms were characteristic of those parts of the river in which the current was moderate or less and the bottom deposits consisted of sand and silt with some attached weed. Another group was characteristic of those parts in which the current was swift and the bottom consisted of stones or stones on a base of blue clay. There was some overlapping, as would be expected, but the general distribution was along these lines. In the centre of the river, except where the islands were present, the very swift current had scoured out the bottom deposits so that only coarse sand or bare clay was present. As would be expected this habitat supported very little animal life. It can be taken, therefore, that animal life is abundant only for a distance of between 150 and 300 feet from both banks in the upper part of the river. Downstream of the islands, the current is less swift, and I found a fair abundance of organisms right across the river.

It will be noticed that the organisms in Table 1 are set out in four groups. These groups correspond to the estimated tolerance of the organisms to pollution. Organisms of group 4 are those which experience, either my own or that of other workers, has shown to be intolerant of pollution. Group 3 organisms are those which are known or considered to tolerate some degrees of pollution, but not very much Group 2 organisms are those which have frequently been found in moderately polluted situations. Group 1 organisms are those which are known to be very tolerant of pollution.

This grouping is regarded at this stage as preliminary only. It is considered that if possible it should be verified by quantitative tests with the type of pollutants which may be encountered in the particular environment under study. Even this would still leave room for the criticism that it would be practical to test only certain stages of the life history of the organism. However, if regard can be had both to the tolerance as measured in toxicity tests and the occurrence in situations of known pollution a considerable degree of confidence can, I suggest, be attached to these groupings.

Groups 1, 2 and 3 organisms, although more tolerant of pollution than those of group 4, can and do live in unpolluted situations. It is the absence of the less tolerant organisms and not the presence of the tolerant ones which gives a reliable indication of pollution.

The method of using these groupings is to allocate a score to each sample according to the presence in it of organisms of the different groups on the following basis:-

Animals of Group 1 present	1 point
Animals of Group 2 present	2 points
Animals of Group 3 present	3 points
Animals of Group 4 present	4 points
Maximum score: 10 points	

Some weighting is given for numbers. Thus, if only one specimen of a group 4 organism is found in a sample a score of 1 instead of 4 is given. Likewise for two specimens a score of 2. This system is quite arbitary but it makes allowance for the fact that a single specimen in a sample may be fortuitous, or merely indicate that an intolerant organism has a toe-hold in an unsuitable environment.

This method of scoring enables the results to be set out graphically giving scores from 0 to 10 vertically and distances downstream from the uppermost station horizontally. Because both swift and slow water species are grouped together according to their tolerance no allowance need be made in these graphs for these factors. However, in the centre of the river where the scouring action of the swift current has rendered the bottom unsuitable for any significant amount of animal life it is necessary to restrict comparisons to situations similar in this respect.

In this preliminary survey it was found that in all situations where there was no reason to suspect the presence of pollution all samples had a score of 10. There were some locations in which lower scores were obtained and these were all in situations which were suspect as possible pollution areas. In all these cases, there was a gradual rise in score moving downstream with a return to a score of 9 or 10 at all downstream stations.

Those parts of the river having scores of less than 10 are the subject of further study. As a result of the data obtained from this survey a programme is being planned to separate the complex factors which may account for the results obtained. This programme has not yet been finalized, but among the factors which will almost certainly be investigated are:

1. The nature and origin of bottom deposits and their effects on organisms;
2. the origin and distribution of any toxic substances and their effects on organisms;
3. quantitative methods of survey of both organisms and deposits so that a reliable measure of any changes can be obtained.

Before closing I should like to make one or two general comments. First I should like to assure our friends from across the border that this preliminary survey has shown that if any pollution originates on the Canadian side of the river, it does not extend across to the American side, and vice versa. The reason for it is, of course, the reasonably swift current (4 knots) in the middle of the river and the considerable dilution available because of the very high flow in the St. Clair River.

Another point I should mention is that these biological surveys do not merely indicate the fishery potential of the river. They give a good indication of the general health of the river except for two points. They do not take into account minute quantities of certain substances such as phenols which might cause taste problems and, as bacteriological studies were not included they do not take account of the presence of pathogenic organisms. With these exceptions they give a good indication of the state of cleanliness of the river for all purposes except drinking and possibly swimming.

In this paper I have tried to give you some idea of the work that is being undertaken in a large and complex river environment. In attempting to describe the work while it is still in its early stages I have taken some risk of making statements which I shall later have to retract. This risk has been accepted as the price paid for the advantages of letting others know what is being done in an important international river to avoid serious pollution from arising and also the advantage that might ensue, both to ourselves and others doing similar work, by stating what we are doing and the methods we are using to accomplish it. This enables others to consider our methods and if necessary criticise them. In this way we hope to obtain some useful comment.

TABLE 1

Group 4	Hydropsyche phalerata
	Cheumatopsyche sp.
	Polycentropus sp.
	Phylocentropus sp.
	Ephemora sp.
	Hexagenia sp.
	Stenonema sp. (femoratum)
	Bactisca sp.
	Other Ephemeroptera
	Isogenus sp.
	Other Plecoptera
Group 3	Odonata
	Endochironomus sp.
	Metriocnemus sp.
	Tendipedes sp.
	Other Chironomids include Cryptochironomus sp. and Pentaneura sp.
	Orconectes limosus
	Gammarus fasciatus
	Asellus sp.
	Dugesia tigrina
	Goniobasis spp. (2 species)
	Valvata tricarinata
	Amnicola sp.
Group 2	Gyraulus sp.
	Lymnae sp.
	Physa sp.
	Sphaerium sp.
	Musculium sp.
	Pisidium sp.
	Lumbriculus sp. (L. inconstans)
	Helobdella stagnalis
	Erpobdella punctata
	Glossisiphonia sp.
Group 1	Limnodrilus sp.

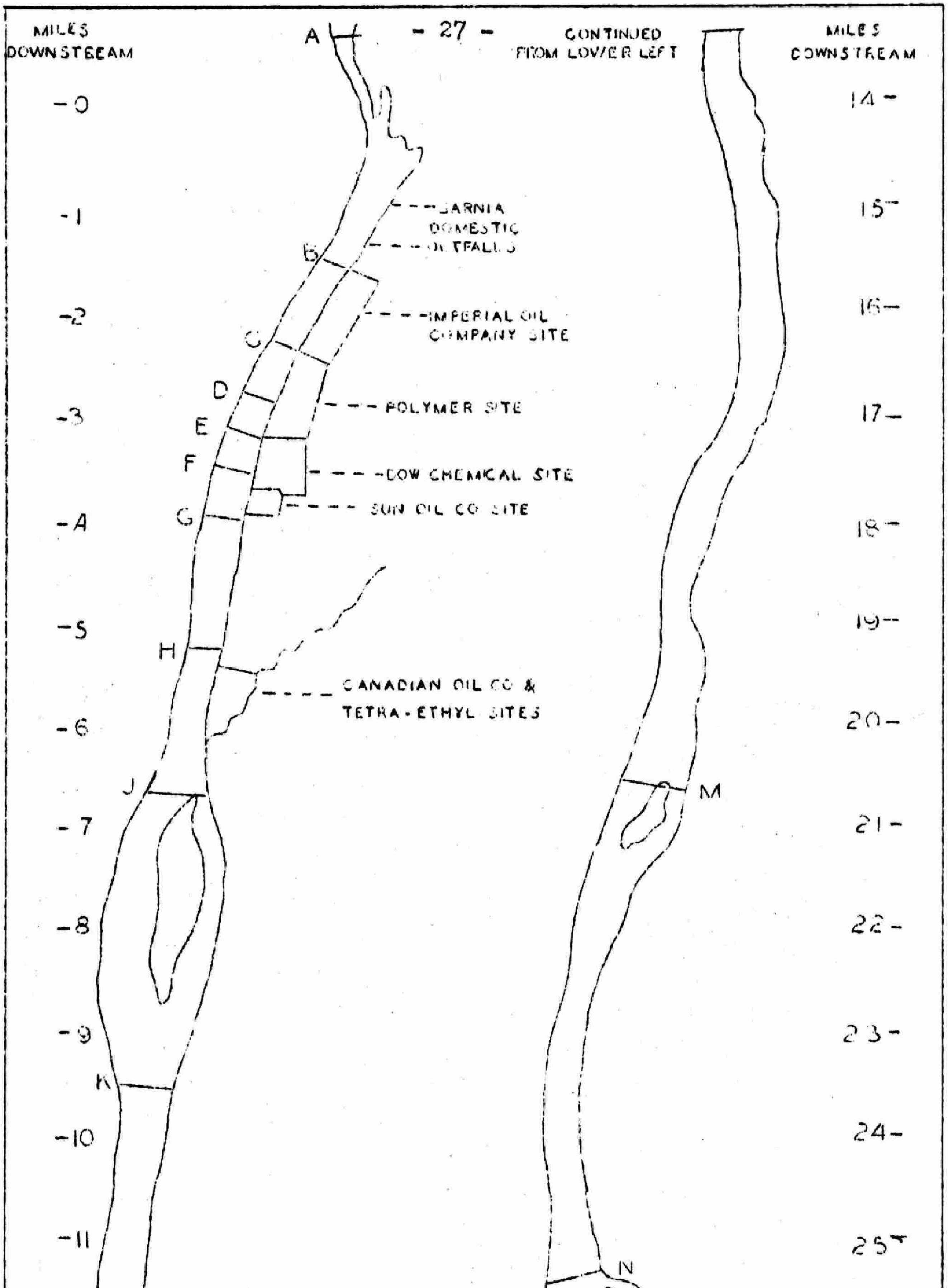

MILES DOWNSTREAM
A
CONTINUED FROM LOWER LEFT
MILES DOWNSTREAM
-0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
14-
15-
16-
17-
18-
19-
20-
21-
22-
23-
24-
25-
SARNIA DOMESTIC OUTFALLS
B
IMPERIAL OIL COMPANY SITE
C
D
POLYMER SITE
E
F
DOW CHEMICAL SITE
SUN OIL CO SITE
G
H
CANADIAN OIL CO & TETRA-ETHYL SITES
J
M
K
N
L
CONTINUED ON RIGHT

FIGURE 1

TOTAL OXIDATION AS APPLIED TO CANNERY WASTE

- by -

J. G. Duncan

Supervisor of Purification Processes
Ontario Water Resources Commission

In considering possible methods of treating cannery wastes, the Total Oxidation Process as worked out by Prof. R. Kountz of Penn State University seemed to offer some advantages over other methods.

(1) It could be brought into operation quickly by trucking in sludge from any activated sludge plant.
(2) There would be no sludge problem if total oxidation was attained.

It was decided in the summer of 1956 to try the process firt on corn waste and the Aylmer plant of Canadian Canners Ltd. was selected as the site to build a pilot plant. There was an old septic tank available as a sludge contact tank. When this was investigated, it was found that there was not time to convert the septic tank and obtain the necessary pump. As a compromise, a small pilot plant capable of handling approximately a gallon a minute was set up, using a small trough alongside the septic tank for sludge contact. Time was still a factor on this smaller plant and, added to this, pump troubles and feed lines plugging with corn waste, the test as a whole could be considered a failure. However, a few short runs were obtained that indicated that the process had possibilities and it was decided to do further work during the summer of 1957.

As there was to be no corn processed at Aylmer in 1957, a new site had to be selected. Two requirements were made:
(1) That the waste to be treated must be screened.
(2) That an electric pump must be available. (The gasoline pump used in 1956 had been very unsatisfactory.)
The Exeter plant of Canadian Canners was selected and a vibrating screen was installed and, as electric power was available at the chosen site, our two requirements were met.

The Exeter plant was to pack peas, corn and sauerkraut, so it was decided to have a pilot plant operating for the pea crop to give a chance to eliminate any operational difficulties before the corn season started and also to get some information on pea waste and pea stack waste as well.

The pilot plant was assembled using a small cooling tank of 1500 gal. capacity for sludge contact, the Dowpack tower of 10 sq. ft. cross section x 63" high that had been used the previous year and a 400 gal. per minute pump that was intended to feed the vibrating screen. From data supplied by Prof. Kountz, this plant would have a capacity of 40 pounds a day of 20 day B.O.D. Sludge was obtained from the activated sludge plant of the R.C.A.F. at Centralia. Some difficulties were encountered. The pump, when checked, delivered only 350 gals. per minute, and difficulty was experienced in setting up a sludge settling area to give a clear effluent. However, the set-up was much better than that of the previous year and was operating reasonably well within a week of the start of the pea pack.

A laboratory was set up in a house located on the cannery property. C.O.D., dissolved oxygen and settleable solids were determined there. Samples were also expressed to the Experimental Station three times a week for determination of B.O.D., total suspended and dissolved solids, free ammonia, total Kjeldahl nitrogen, nitrites, nitrates, and phosphorous. Composite samples were taken at hourly intervals.

When it was found impractical to do 5 day B.O.D. determinations on all samples, it was hoped that a factor could be found to convert C.O.D.s to 5 day B.O.D.s. The relation between the two determinations varied too widely to be of any use. Interferences were noted in D.O. determinations and also in the nitrogen and phosphorous analyses. The results of these tests were felt to be of questionable value.

Nutrients were added at the rate of 3 pounds of nitrogen and 1 pound of phosphorous for each 100 pounds of 5 day B.O.D. These quantities were recommended by Mr.R.A. Canham of the National Canners Association and were maintained for the whole period of the experiment.

The plant was put in operation with an activated sludge containing 1026 ppm suspended solids and a sludge volume index of 118. The first two weeks were used to build up the sludge and to clear up operating difficulties. During this time, the suspended solids in the sludge built up to 6448 ppm and the sludge volume index varied from 265 to 152. B.O.D. and C.O.D. removal at this stage was encouraging.

For the last nine days of the pea pack, it was attempted to maintain a load of 40-50 lbs. of C.O.D. per day on the plant. This was fairly successful except for one day when the load climbed to 80 pounds of C.O.D. With the exception of this one day, the results were very good. Suspended solids in the sludge varied from 5000 to 70000, the sludge volume index varied from 138 to 188. C.O.D. removal averaged better than 94% and removal of 5 day B.O.D., from a limited number of results, averaged better than 95%. The results of the analyses for the one day that the plant was heavily overloaded would indicate that it was capable of taking a shock load and recovering quickly.

For the next two days, the plant was operated on pea stack waste plus wash water and the results continued very good. During the following week, when the cannery was being cleaned there was a good deal of alkali and detergents in the waste, and feed to the pilot plant was discontinued for this period but the sludge was recycled. For the next two weeks, pea stack waste, diluted with plant drainage, was fed continuously to the pilot plant. In this period, suspended solids in the sludge dropped to 3200, and the sludge volume index climbed to 270, and the efficiency of the plant was declining.

The corn pack started at this time and for the first week's operation. The efficiency of the plant was not good, but the sludge seemed to be recovering. At this point, the motor operating the recirculating pump burnt out, and the pilot plant did not operate for one week. During this time the sludge was recirculated with a small gasoline pump at a rate of approximately 50 gals per minute to keep the sludge from going septic.

For the next four days, the plant was operated on corn waste. The % removal of C.O.D. climbed to 94.6 and indications were that it was regaining the efficiency it had when operating on pea waste. The following day there was no corn packed and pea stack waste was fed. This was apparently a serious mistake as the quality of the sludge deteriorated rapidly. It no longer flocked and had a slimy appearance, and in the next ten days the efficiency in C.O.D. removal dropped to 50%.

During the last ten days of the corn pack, the plant made a gradual recovery that was slowed up by overfeeding and never did return to its earlier efficiency.

In estimating a power requirement for this process, it was felt that it was better to use C.O.D. values rather than 5 day B.O.D. on account of the few B.O.D. determinations made. Assuming a total head of 10 ft. and an efficiency of 70% for motor and pump, the power consumption per lb. of C.O.D. per day would be 0.7 KWH.

Conclusion

The pilot plant was capable of oxidizing cannery waste at a rate of 40-50 lbs. of C.O.D. per day. This checks very well with Prof.Kountz' calculated capacity of 40 pounds of 20 day B.O.D. per day.

Pea canning waste can be successfully treated by this process.

Pea stack waste in the early stages of fermentation can be treated, but as fermentation progresses the waste becomes more difficult to treat and in the later stages is deleterious to the process. However, this later-stage pea stack waste when well diluted with corn waste can be treated without serious interference.

Though good results were not obtained in treating corn waste due to the interference from pea stack waste, it was felt that the plant could handle corn waste successfully.

The sludge produced was very stable and had the capacity to handle heavy overloads and recover quickly afterwards.

Two difficulties were encountered that changes in designmmight overcome. (1) With settled solids in the range of 95-98 per cent, it is difficult to separate a clear effluent. (2) The high rate of recirculating of the sludge means that some of the waste has a very short contact time, resulting in a higher B.O.D. content in the effluent than is desirable.

A table of the results for the whole period of the research is given below.

RESULTS OF TOTAL OXIDATION RESEARCH

CANADIAN CANNERS LTD. PLANT AT EXETER

	SLUDGE			COD				BOD 5 DAY			GALS
DATE	SUS. SOLIDS	SETTLEABLE SOLIDS	V. INDEX	RAW PPM	EFFL. PPM	% REMOVAL	#1 DAY REMOVAL	RAW PPM	EFFL. PPM	% REMOVAL	TREATED
JULY 17	1026	12	118	2623	116	96.2	7.6				300
18	1200	14.5	120	2428	118	95.3	8.3	896	15	98.3	360
19	1200	24	200	2581	118	95.3	8.1				330
20				3748	149	95.7	11.3				315
24	1934	32	165	3633	172	95.2	25.0				720
25	2464	64	260	4072	186	95.5	28.0	4420	31	99.3	720
26	2924	78	265	3824	197	94.9	26.1				720
27				4835	285	93.8	32.7				720
28				3931	288	92.7	15.3				420
29	4012	98	245	3792	1080	71.5	39.1	3920	308	92.1	1440
30	3798	75	198	3303	455	86.2	20.5	500	110	78.0	720
31	5420	98	180	8997	1147	87.3	57.0	1722	413	76.2	720
AUG. 1	6448	98	152	8389	1673	74.4	48.3				720
			END OF	ADJUSTMENT PERIOD							
2	5048	95	188	6295	430	93.2	28.1				480
3				5910	430	92.6	26.3				480
4				10174	419	95.9	46.8				480
5	5384	97	180	11328	447	96.1	52.3	5600	153	97.2	480
6	4890	96	196	6432	507	92.2	28.5	10280	298	96.0	480
7	7016	98	138	9850	460	95.3	44.8	2540	118	95.3	480
8	2434	95	390	14130	1265	90.0	80.2	3290	450	86.3	630
9	5972	98	164	7409	402	94.6	33.7				480
10				11233	428	95.9	51.7				480
		END OF PEA PACK									
11						86.9	51.1				180
12	7800	98	125			94.3	53.5	7000	186	97.3	510
13	7216	98	135	NO FEED DURING THE							
14	7170	98	136	CLEAN UP							
16	6492	98	150								
19	5920	98	165			97.2	31.2	9320	184	98.0	210
20	6430	98	151			95.8	65.1	12920	473	96.3	480
21	9132	98	106			94.1	33.5	5640	126	97.7	380
22	2990	98	325	4230	480	88.6	27.3				730
23	5538	90	162	3950	454	88.2	50.3				1440
24				2656	346	87.0	33.3				1440
25				5875	277	93.7	80.6				1440
26	6070	97	160	3708	271	92.7	49.3	5528	1912	66.0	1440
27	4770	97	203	1876	208	88.8	39.9	1360	76	94.4	2400
28	3776	95	250	1810	202	88.8	46.1	1140	46	95.9	2880
29	3758	93	247	1548	202	87.4	40.2				2880
30	3234	82	270	1294	204	84.5	31.5				2880
31				2223	211	90.4	57.9				2880
SEPT 1				2320	209	90.9	20.2				960
	START OF CORN PACK										
3	2758	92	330	3190	294	90.7	26.1	2720	56	97.9	900
4	4010	77	190	3557	693	80.5	27.4	2120	252	88.2	960
5				2771	636	77.2	20.5				960
6	4306	94	217	3374	829	75.3	18.3				720
7				3987	1003	74.7	21.5				720
8				1518	552	63.5	6.9				720
9				4005	445	88.8	25.6	4760	176	96.3	720
10	4026	96	238	2451	446	81.8	14.4	2220	246	88.9	720
	MOTOR OPERATING LARGE PUMP BURNED OUT										
18	3720	97	260	3744	255	93.2	16.8	3360	232	93.8	480
19	3624	97	266	4067	277	93.2	27.3				720
20				2296	168	94.3	23.0				1080
21				2893	155	94.6	39.5				1440
22				1311	157	88.0	16.6				1440
23	2752	92	334	2983	441	85.2	36.6	1480	172	88.4	1440
24	1203	90	745	3327	687	79.4	38.0	4080	418	89.8	1440
25	4160	88	211	9996	958	76.0	43.7	3560	532	85.0	1440
26	4740	67	141	3489	1293	63.0	31.6				1440
							C%.				

(CONT)

		SLUDGE			COD				BOD 5 DAY			GALS
DATE		SUS. SOLIDS	SETTLEABLE SOLIDS	V. INDEX	RAW PPM	EFFL. PPM	% REMOVAL	#1 DAY REMOVAL	RAW PPM	EFFL. PPM	% REMOVAL	TREATED
SEPT	27				5310	1413	73.5	50.2				1440
	28				5796	1890	61.3	56.3				1440
	29				5040	1962	61.0	44.3				1440
	30				3852	1953	49.9	27.4	2480	1148	53.5	1440
OCT.	1	8558	98	114	3708	1359	63.3	33.8	3480	568	82.7	1440
	2	6666	98	147	4339	1229	71.5	31.1	4720	530	88.8	960
	3	6200	98	160	3001	1229	59.0	38.3				2160
	4	5292	100	190	3327	1157	65.0	46.9				2160
	5				4122	801	80.6	47.9				1440
	6					NO FEED						
	7	4060	100	245	3294	801	75.5	53.9	3440	432	87.6	2160
	8	3664	98	268	4068	576	85.8	75.5	4160	240	94.2	2160
	9	3238	98	305	3708	882	78.5	61.4	2360	172	92.7	2160
	10		100	325	2448	936	61.6	32.7				

MILL SCALE SEDIMENT PRACTICE

- by -

Richard D. Hoak

Mellon Institute
Pittsburgh, Pa.

The steel industry is a large user of water, but it consumes only a small fraction of its intake. Roughly 75 per cent of the water taken by a steel mill is used for cooling and returned to streams practically unaltered. Conservation of water is practiced increasingly through reuse of cooling water for other purposes. Process water is needed for certain operations, such as direct cooling of coke oven gas, washing blast furnace gas, carrying scale away from rolling mills, and the like. These waters are more or less contaminated, and they are treated in various ways before being discharged. The steel industry has long recognized its responsibility for preservation of water quality for downstream uses by supporting research on waste treatment and pollution control. This paper deals with one aspect of that research.

Mill Scale and Stream Pollution.

The manufacture of various steel products entails rolling hot metal into desired shapes. Hot steel oxidizes in air, and the film of oxide scale thus formed must be removed from the metal just before rolling. This is ordinarily done by directing a water spray onto the metal surface immediately ahead of the rolls. Most of the scale drops into a flume and is carried by a stream of water to a scale pit.

Rolling-mill scale is not a waste product. It contains upward of 70 per cent iron as a mixed oxide and is equivalent to high grade iron ore. For this reason it is recovered as completely as possible for reworking. Scale particles range in size from an inch or more in breadth to a micron or less. Roughly 90 per cent of the scale particles settle rapidly in water, and recovery of this portion of the total is not a serious problem. The 10 per cent that settles quite slowly is difficult to recover in typical scale pits. Opinion is divided over the desirability or necessity of removing some proportion of this finely divided material from waste water before it is sent to the sewer. Unfortunately, there is no satisfactory basis for resolving this question.

Regulatory agencies generally maintain, as a matter of principle, that discharge of suspended solids impairs water quality. Application of this principle to an actual situation is difficult. There are no quantitative criteria that can be used to define the impairment that would result from various concentrations of different kinds of suspended solids. In addition, the effect of natural silt is often disregarded. The general attitude appears to be that discharge of man-made suspended solids can, and therefore should be limited. It does not follow, however, that more or less complete removal of man-made suspended solids from waste water can always be justified on the basis of an improvement in the receiving water. Where such material is a relatively small percentage of the normal load of natural silt its removal would usually have an inappreciable effect.

Scale pits vary widely in design. Most of the pits were installed many years ago, and their sizes and shapes were usually dictated by the available space and location. The object was to recover most of the heavy scale for smelting in open hearths or blast furnaces after sintering. Discharge of particles too fine for easy recovery did not seem to have a significant effect on the receiving water. On the other hand, salvage of the coarse particles had to be rather efficient if clogged sewers were to be avoided. The increasing attention being given to the presumed effects of various kinds of waste waters has made it necessary to appraise the effectiveness of mill scale recovery practice. The first step in such an appraisal is to measure the efficiency of existing equipment. Following this, it will be necessary to evaluate the effects on water quality of suspended solids now being discharged. Then, where water quality is actually being impaired means will have to be developed to reduce the discharge to an acceptable level.

Flue Dust Recovery Practice.

Rolling mills are not the only sources of water-borne suspended solids in the steel industry. Blast furnace gas contains considerable particulate matter (flue dust) which must be removed before the gas can be used as a fuel. The dust is nearly always washed from the gas with water, and the resulting suspension is clarified by sedimentation. Although some mills had a fair idea of the effectiveness of their dust recovery equipment, the industry as a whole did not know very much about the efficiency of its dust recovery practices. As a result, the Steel Industry Action Committee of the Ohio River Valley Water Sanitation Commission (ORSANCO) conducted a survey at the 23 mills operating blast furnaces along the Monongahela and Ohio Rivers. Before making the survey it was necessary to develop uniform sampling and analytical procedures. This was undertaken by the American Iron and Steel Institute Fellowship.

The concentration of suspended solids in gas-washer water fluctuates over a wide range as a function of normal variations in furnace operation. Thus it was essential to develop a sampling procedure that would provide data truly representative of clarifier performance. An intensive study was made at a typical clarifier installation to establish a proper sampling program. Samples of influent and effluent were collected at 20-minute intervals for two hours on each of 23 days over a period of two months and analyzed individually. The results were compared with data from hourly samples collected over a 24-hour period and analyzed individually, and with the results from 15-minute and 60-minute composite samples collected over the same period. Statistical analysis of all the data showed that the average of individual samples over a 24-hour period was within the confidence interval of samples taken over a much longer period of clarifier operation. Also, the composited samples did not deviate enough from the long-term averages to invalidate this method of sample collection. The survey was, therefore, based on hourly samples composited for 24 hours.

The performance of sedimentation equipment is judged by the efficiency with which it removes settleable solids. But settleable solids are defined by an arbitrary analytical method originally devised for domestic sewage. Flue dust particles have a much greater density than sewage solids and therefore settle more rapidly. Settling rate studies on flue dust showed that 80 to 98 per cent of the total suspended solids settled in 15 minutes, depending upon the initial concentration. Typical settling curves are shown in Figure 1. It is apparent that the settling period chosen as a measure of the settleable solids content of washer water will have a marked effect on the nominal efficiency of a settling device.

The 60-minute quiescent settling time prescribed in Standard Methods was retained in the analytical method developed for the survey. Although 60-minute settling provides a large safety factor, this period is firmly fixed as a measure of settleable solids. The only important departure from the standard method was the determination of both settleable and nonsettleable solids, by weight, on the same sample portion. This was done because the rapidity with which settling occurs makes it difficult to portion a sample accurately; the recommended procedure avoids any question about the validity of the analysis.

The performance of flue dust clarifiers was defined by an index which provides a measure of the effectiveness of removal of settleable solids. The performance index is given by the relation

$$\frac{\text{Total Influent Suspended Solids - Total Effluent Suspended Solids}}{\text{Influent Settleable Solids}} \times 10$$

Questionnaires returned by the 23 operators of blast furnaces in the Ohio Valley provided data from which flue dust production and recovery could be evaluated. The results of the survey have been published by ORSANCO under the title, "Dust Recovery Practice at Blast Furnaces."

Mill Scale vs. Flue Dust.

The useful information derived from the flue dust survey led naturally to a proposal that a similar evaluation be made of mill scale recovery. This, however, turned out to be a much more difficult problem. Although the concentration of suspended solids in blast furnace gas-washer water fluctuates widely, it is possible to determine the average concentration by a statistically sound sampling program. This permits calculation of a material balance on recovery equipment. In spite of the wide range of concentration of suspended solids in gas-washer water the particles are small enough to stay in suspension where there is only moderate turbulence. This is not true of mill scale. The heavy pieces of scale flow along the bottom of the flume that carries the scale away from the rolling mills and only the finer particles are suspended in the water. The non-uniformity of the suspension makes it impossible to collect representative samples of scale flowing to a recovery pit, and a material balance cannot be made directly.

Evaluation of Scale-Pit Performance.

It is the finely-divided scale particles that are difficult to remove in conventional scale pits. Therefore, the first approach to the problem was an attempt to evaluate scale-pit efficiency in terms of its effectiveness in settling particles coarser than some critical size. Particle-size distribution analyses were made upon many influent and effluent samples from a number of scale pits. The results were quite erratic because of the difficulty of getting representative samples. In addition, the smallest particle that could be settled ap-

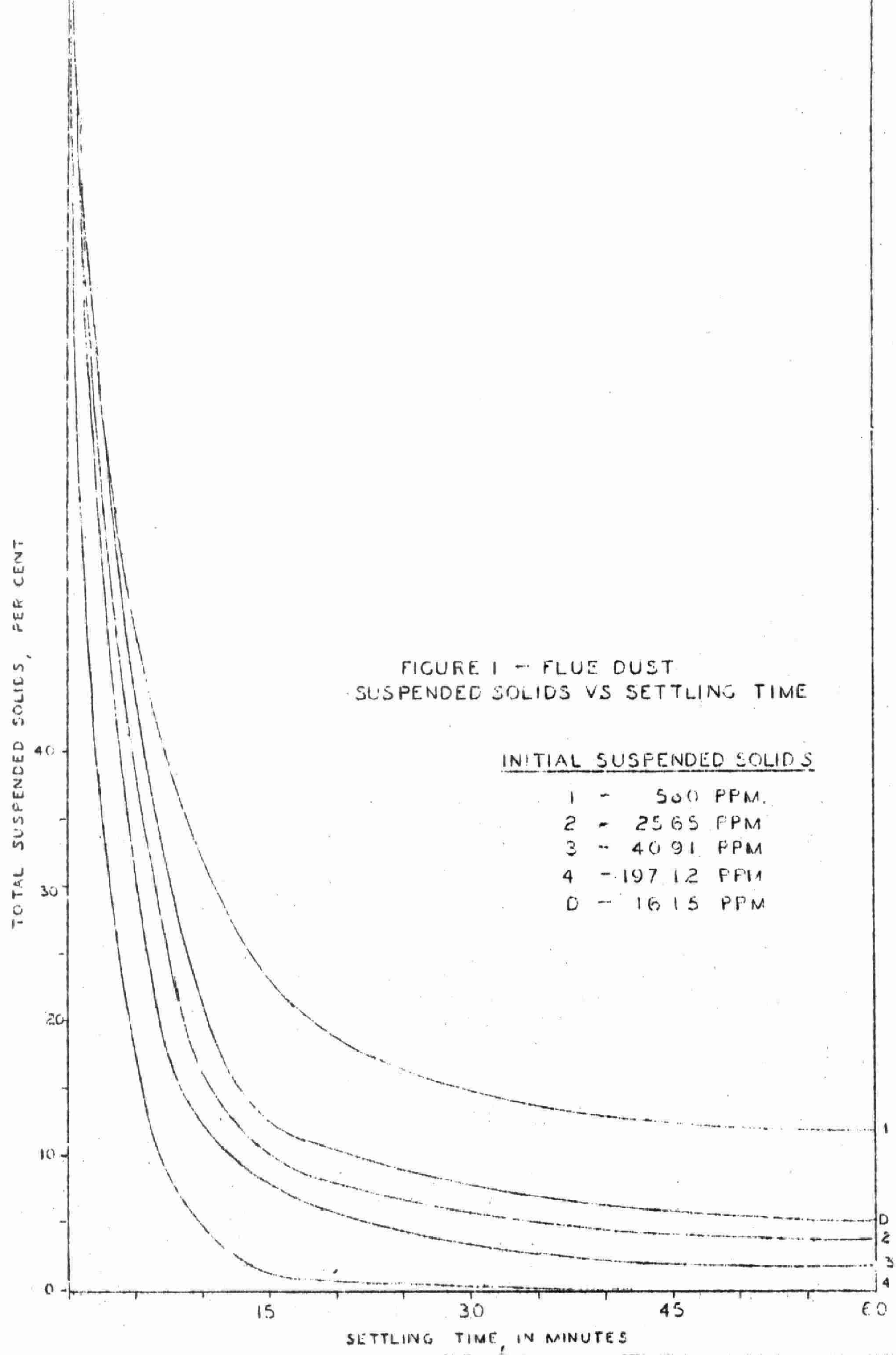


FIGURE I — FLUE DUST
SUSPENDED SOLIDS VS SETTLING TIME

peared to vary with pit design and operation, as well as with the kind of stock being rolled.

The problem was next attacked by collecting laboratory data on the settling rate of particles flowing into scale pits. This was done by scooping a quantity of water from the flume and quickly decanting it into a series of liter beakers. The concentration of particles in suspension at various intervals of time was determined by syphoning 250 ml from the midpoint of a beaker and filtering. A group of settling-rate curves is shown in Figure 2. These data were collected in the course of sampling several scale pits. The pits were cleaned before and after each run. The average concentration of total influent suspended solids was calculated from the weight of scale dredged, the flow of water, and the average concentration of total effluent suspended solids; the influent concentration is shown for each curve. A comparison of these curves with those of Figure 1 shows that mill scale settles much faster than flue dust.

The accuracy with which scale-pit effluents can be sampled has often been questioned. A continuous sampler appeared to offer the best chance of getting representative samples, and a suitable device was developed. It consists of a vertical pipe through which a considerable volume of effluent is lifted by an air ejector at a steady rate. The water discharges into a disengaging chamber from which a small stream is drawn at a constant rate to provide samples at any desired frequency. It was thought that the continuous sampler might not pick up particles as heavy as would be caught in a grab sample. A comparison was made by passing a series of continuous and grab samples through a set of screens. This showed that the two methods are equivalent, but that the continuous sampler furnishes a more precise average analysis.

A study of several pits under quite different operating conditions has provided information that may lead to a practical method for evaluating pit performance.

The difference between settling suspended solids in a laboratory beaker and in a scale pit is found in the degree of turbulence. The velocity head of the influent stream must be dissipated in order to have quiescent settling, and it is the degree to which this is accomplished that determines the relationship between theoretical retention time and equivalent quiescent settling time. A very interesting point emerges when laboratory settling data are extrapolated on semi-log paper. Where the concentration of suspended solids in a pit effluent intersects the pertinent settling curve the equivalent quiescent settling time is found to be roughly 0.1 minute. Four settling curves are shown in Figure 3. Influent solids remaining in suspension were determined after quiescent settling in the laboratory for several periods of time, and straight lines through the plotted points were extended to the ordinate. The data are given below.

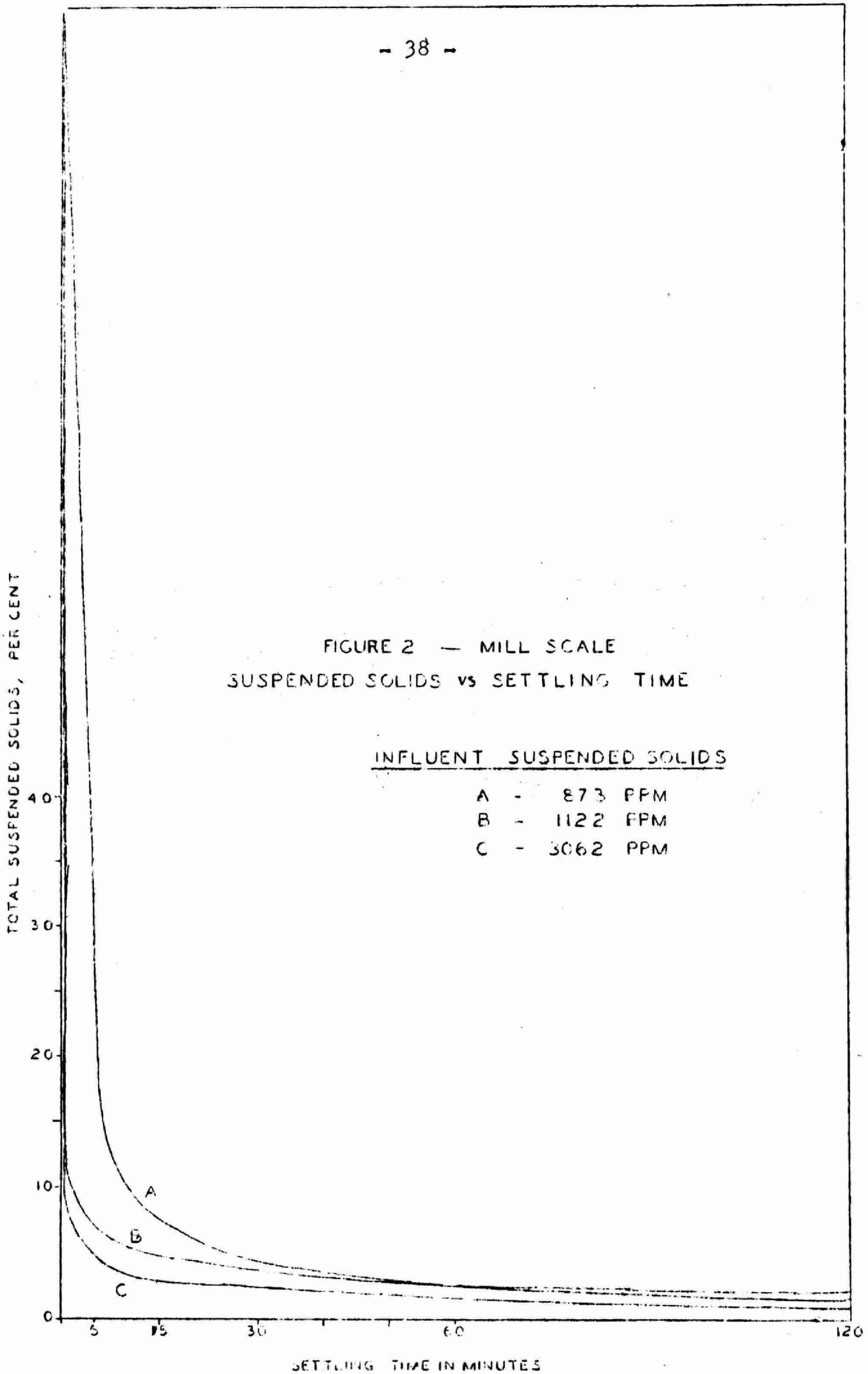


FIGURE 2 — MILL SCALE
SUSPENDED SOLIDS vs SETTLING TIME

Pit	NSS in Influent, ppm					TSS, ppm	
	5 min	15 min	30 min	60 min	120 min	Influent	Effluent
A-1	-	67	38	22	12	873	191
A-2	-	33	26	15	7	1099	102
B	73	53	44	28	24	1122	155
C	147	108	73	50	25	3062	267
D	-	201	126	86	-	1615	105

Note: NSS = nonsettleable solids; TSS = total suspended solids

An example will illustrate how equivalent quiescent settling times are obtained from Figure 3. Extend a straight line from ordinate 191 to its intersection with curve A-1 and read 0.1 min on the abscissa. This indicates that, had the influent suspension been allowed to settle quiescently for 0.1 min, the solids in suspension would have been 191 ppm, corresponding to the actual effluent concentration. Unfortunately, a laboratory settling time of five minutes is about the shortest interval for which dependable data can be obtained, and the graphical finding cannot be checked experimentally. The curves A-1 and A-2 represent data on a pit before and after installation of a baffle; these curves are not directly comparable, however, because the rolling schedule was quite different on the two occasions.

An equivalent quiescent settling time of 0.1 min seems scarecely credible, even though the water in an average scale pit is obviously quite turbulent. The method used to derive equivalent quiescent settling times may be criticized on the basis that laboratory data were extrapolated too far.

On the other hand, support for the concept may be found in data on flue dust. Curve D shows laboratory data on the settling rate of flue dust. It may be seen that intersection of ordinate 105 with curve D indicates an equivalent quiescent settling time of 46 min, and that this result falls within the laboratory data. The data given in the table above represent averages from four runs on a Dorr clarifier.

Another approach is possible through the use of Reynold's number as a criterion of turbulence. Tabulated below are the dimensions, theoretical retentions, equivalent quiescent settling times, and Reynold's numbers for three scale pits and a flue-dust clarifier.

Plant	Dimensions			Theo. Retention Time, min	Equiv. Settling Time, min	Reynold's No.
	L	D	W			
A-2	50'0"	8'0"	10'0"	7.2	0.06	133,000
B	35'0"	9'0"	18'0"	8.5	0.10	114,800
C	69'9"	12'0"	17'6"	12.6	0.19	96,000
D	90'	diameter		87.0	46.0	24,550

It can be seen by inspection that there is a relationship between the three variables. Equivalent quiescent settling times increase with increases in theoretical retention times and decreases in Reynold's numbers. These data illustrate the fact that the finer the particles the more difficult it becomes to settle them in conventional equipment under normal operating conditions.

Summary

A study of several mill-scale pits and a flue dust clarifier suggests that there is a relationship between theoretical retention time, equivalent quiescent settling time, and Reynold's number that may provide a practical method for evaluating and predicting the performance of sedimentation equipment.

This investigation is still in an early stage. It is being continued to determine whether the relationship described is valid, and whether it will have to be refined before it can be put to practical use.

Acknowledgement

This paper is a contribution from the Multiple Fellowship that the American Iron and Steel Institute has sustained at Mellon Institute since 1938.

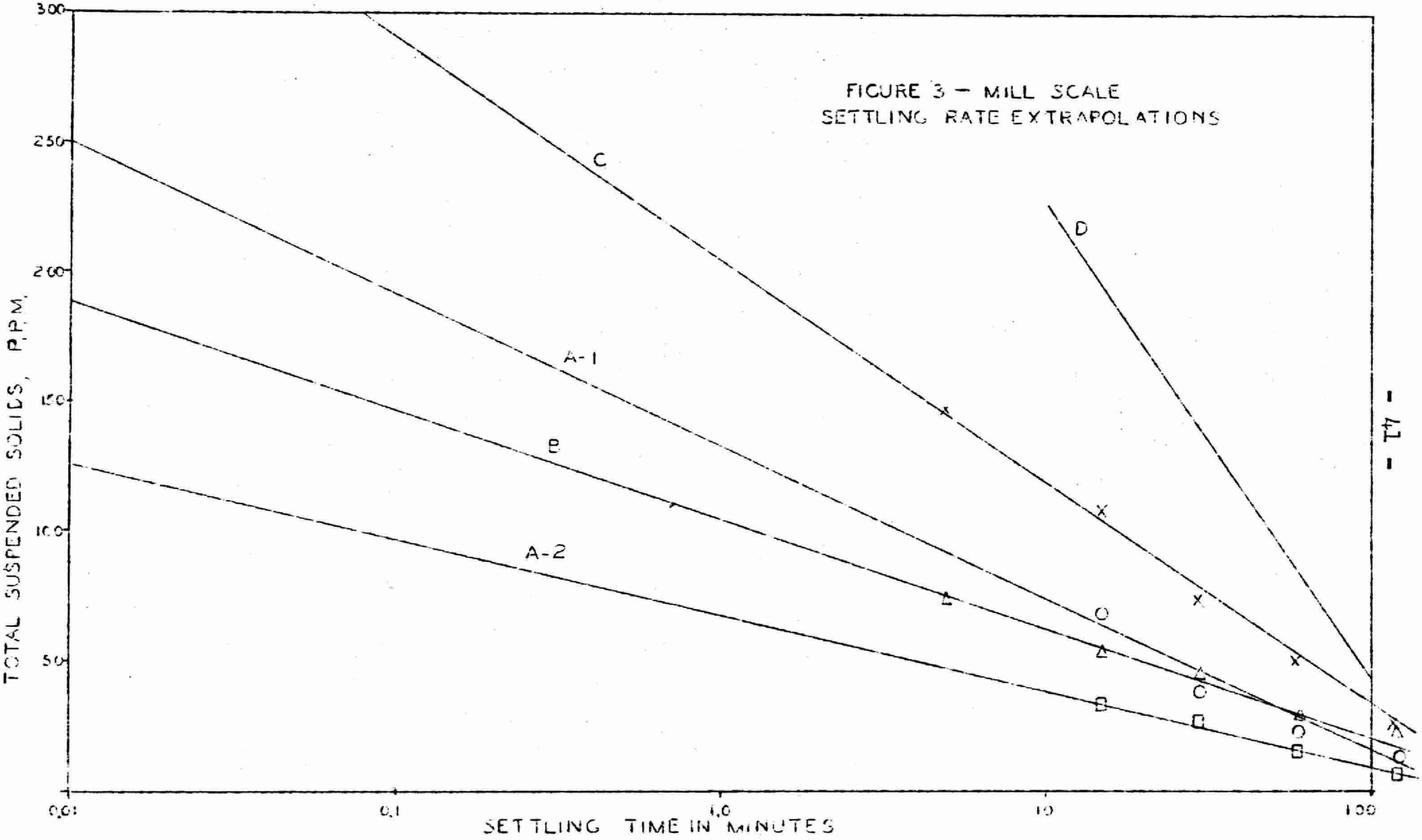


FIGURE 3 — MILL SCALE
SETTLING RATE EXTRAPOLATIONS

COMMERCIAL DEPHENOLIZATION OF AMMONIACAL LIQUORS WITH CENTRIFUGAL EXTRACTORS

- by -

Walter E. Carbone
Ralph N. Hall

Wilputte Coke Oven Division

- and -

Herbert R. Kaiser
G. Clyde Bazell

Podbielniak, Inc.

The elimination of phenol from coke plant ammonia liquor has been a problem of major concern to the industry for many years, and in this connection the Wilputte Coke Oven Division and Semet-Solvay Division of Allied Chemical Corporation, have devoted considerable effort over a period covering more than 25 years towards the development and design of a phenol removal or recovery plant which will result in an installation having the features of high efficiency, operating charges as low as possible, and lowest investment. The type process which appeared to have possibilities of attaining these advantages was the solvent extraction process, whereby raw ammonia liquor is contracted counter-currently with a solvent readily available in the coke plant, such as light oil. The solvent removes the phenol, and in turn is treated with a caustic soda solution for extraction of phenol as sodium carbolate, and thence the solvent is recycled. Various types of equipment have been used in the process, progressing from static decanters for separation of premixed liquor and solvent, to static contacting chambers or towers equipped with trays, packing, or other contacting media.

During the past 15 years, the Podbielniak Corporation developed a so-called centrifugal extractor having multi-stage, for liquid extractions, in another industry. In 1953, this machine was brought to the attention of Wilputte's engineering and research departments, and from previous laboratory scale tests conducted by Podbielniak this new machine appeared to have the potential of high phenol removal efficiency. In view of this, Wilputte, aided by the previous experience gained by Podbielniak, proceeded with an intensive research programme during the major portion of 1954 at the Semet-Solvay Coke Plant in Ironton, Ohio, whereby a complete pilot unit utilizing Podbielniak centrifugal extractors was used to dephenolize actual production ammonia liquor with light oil continuously.

In 1956, Mr. H. R. Kaiser of Podbielniak, Inc. presented a paper titled "Dephenolizing with Centrifugal Extractors" before a meeting of the Chicago Blast Furnace & Coke Association, and the pilot plant investigation was discussed at that time.

The results obtained in the pilot operation were extremely encouraging, and it was then decided that the Wilputte Coke Oven Division would standardize on this type plant, using data obtained from the pilot operations for design of a full scale commercial plant.

In September 1955, the Weirton Steel Company, Division of National Steel Corporation awarded a contract to Wilputte for the first commercial installation having a capacity to handle 200,000 gals of weak ammonia liquor per day. This plant was officially placed in operation December 31, 1956 and has now been in operation for more than one year.

SLIDE #1 - Shows the exterior view of this plant.

The building houses the two Podbielniak extractors, pumps, process control board, and electrical room. Outdoors we have phenolized and dephenolized liquor tanks, caustic and carbolate storage tanks, and ammonia liquor coolers.

You may note that this is a type of installation that lends itself readily to good housekeeping and easy maintenance.

SLIDE #2 - Shows the interior view of the extractor building.

Note the extractors, control board, etc. The use of the centrifugal extractors for handling this considerable volume of liquor certainly presents a striking comparison to the tall, large diameter towers required in the static type plant.

A great deal of information concerning the centrifugal extractors is available in the literature and I will not go into detail to explain the internal construction at this time. However, it is interesting to compare the rotor with a perforated plate column. The centrigual contactor is very similar in that the plates of the columnsare wrapped around a shaft and rotated to develop a centrifugal force field, which is approximately 2000 times that available in the gravitational column.

SLIDE # 3 - Simplified process flow sheet.

Herek a simplified version of the process is shown diagrammatically, and for our purposes, the raw ammonia liquor previously freed of tar and other solid carbonaceous matter, is pumped from storage tank (1) and enters the centrifugal extractor (2) where it flows in a continuous countercurrent manner to dephenolized light oil from oil pump tank (4). The dephenolized ammonia liquor then leaves the extractor (2) and is stored or handled through storage tank (3) for subsequent treatment in coke plant. The action taking place in the extractor is one of continuous, countercurrent mixing and separation of two liquid phases in the elements of the spinning rotor. Due to the absorptive properties of light oil for phenol, the phenolic compounds are removed from the ammonia liquor during the intimate contacting taking place in the Extractor.

The phenolized oil after passing countercurrently to the ammonia liquor flows to oil pump tank (5) from which it is pumped to the certrifigal reactor (6) a machine of substantially the same characteristics as the extractor, and flows countercurrently to a caustic solution which is pumped from mixing tank (8). This solution and phenolized light oil are subjected to the same action as described for the Extractor, whereby the caustic reacts with the phenol, forming sodium carbolate, which flows from centrifugal Reactor (6) and is stored in tank (9) preparatory to shipping. The dephenolized light oil flows to oil pump tank (4) and is recycled for phenol removal, thus completing the cycle.

Perhaps one of the most significant factors established in our pilot operation was the fact that caustic concentration greatly influenced per cent elimination of phenol from the liquor. The more dilute caustic used, the better the phenol elimination. A carbolate of reasonable concentration must be produced to be saleable, and it was found from our pilot operations that by employing two streams of caustic of different strength as feeds to the Reactor, the desired elimination of phenol and concentration of product could be readily obtained. As mentioned, the flow sheet is a simplified one; in the actual installation a strong caustic stream is introduced in the phenolized oil after pump tank (5) and before the pump suction for removal of the bulk of phenol, and the weak caustic stream is introduced as shown for removal to final value. The two carbolates produced, as well as the excess un-reacted caustic, combine near the periphery of the rotor to form the final strength of carbolate.

The following four slides will show various details of plant construction as well as extractor design, and each shall be discussed briefly:

SLIDE #4 - Front diagonal view of extractors.

This view shows the arrangement of piping to and from the centrifugal contactor. Liquids must be transmitted from the stationary piping to the rotating element by means of hydraulically balanced mechanical seals. Each rotating element is constructed of type 316 stainless steel and is mounted on heavy-duty roller bearings.

SLIDE #5 - Rear view of extractors.

This view shows the manner in which the rotors are driven. These are gyrol fluid drives which provide an infinte spded range from zero to motor speed. The Extractor unit operates at 1750 rpm and the Reactor unit operates at about 1500 rpm. Power is transmitted from these drives to the rotor by static free belts.

SLIDE #6 - Extractor flow diagram.

This slide shows the flow of liquids through the Extractor unit. Within the spinning rotor, contact and phase separation are effected continuously and countercurrently by the contact elements. Liquids are pumped into the rotor via two sets of distribution manifolds: Shown here; one set is located near the center while another set is located near the outer diameter of the rotor. The light oil phase is pumped to the outer manifold and the heavy ammonia liquor phase is pumped to the inner manifold. In the high centrifugal field the heavy phase moves outward, displacing the light phase toward the center of the rotor. In this manner, countercurrent flow is achieved.

The liquids pass through contacting elements in the flow region to effect intimate mixing; phase separation occurs between the elements, and efficient extraction results.

Quiet zones at the outer diameter, and at the center of the rotor produce clarified effluents.

Centrifugal force in the range of 2000 times gravity insures positive multistage mixing of the two phases.

Retention time of the liquids within the rotor is approximately 45 seconds.

SLIDE #7 - Reaction flow diagram.

This slide shows flow of liquids through the Reactor unit. Within this rotor oil and caustic flow ratios are in the order of 150/1, and for efficient dephenolization, 150 gallons of light oil must be intimately contacted with 1 gallon of caustic solution. This contact is enhanced by one of the more important operating characteristics of the machine whereby the main interface is controlled by back pressure regulation.

The back pressure control valve shows in the view acts to restrict the light liquid out phase. By variation of this restriction, the relative volumes of each phase held within the rotor on the main interface can be controlled and maintained independent of the actual flow ratios.

In this unit, it is desirable to maintain the rotor almost filled with the caustic phase. This is accomplished by maintaining a minimum back pressure setting.

We have discussed the various physical aspects of the Weirton plant and some phases of the equipment design, and at this time we believe that a presentative of actual operating data and performance will be of interest:

SLIDE #8 - Graph of operating data.

This slide shows the operating data for a one month period, October 23 to November 23, 1957, plotted in graphical form.

Three curves prepared from plant laboratory control records of the Weirton Steel Corporation are shown; phenol content of raw liquor, phenol content of treated liquor and the removal efficiency.

Samples were taken at 2-hour intervals and combined to form composite samples, representative of a 24-hour period of operation. Analyses were determined by the colorimetric method which is now the standard method employed by most coke plant laboratories and is known as the DAAP or the 4 amino-antipyrene method.

Note that the average phenol content of raw or untreated liquor is approximately 3000 PPM.

Following treatment, this phenol value was reduced to about 35 PPM.

Calculation of percent phenol eliminated shows an overall efficiency of approximately 98.8%.

The average removal efficiency throughout this period was between 98.2% and 99.5%. It is interesting to note that 99.0% elimination or better was achieved on thirteen days of the period shown.

The peaks noted on November 13 and 17 on the phenol removal curve are rather unusual, and we believe these are probably due to some errors made when samples were obtained, or contamination occurring when the composite samples were accumulated.

Caustic consumption throughout this period was maintained continuously at one pound of caustic per pound of entering phenol.

In order to maintain this caustic ratio, the solution flow rates were periodically adjusted by the operator from a precalculated chart based on phenol content and flow rate of untreated ammonia liquor.

While some variation in light oil to liquor flow ratios took place during the period, the ratio was generally about 1.25 to 1.0.

SLIDE #9 - Extractor Operating Data:

The normal plant operation for the Extractor unit is shown by this slide.

The rotor is operated at about 1750 RPM. Liquor is received at the plant at about 65°C and cooled to about 40°C in shell and tube type coolers prior to entering the Extractor unit.

Weak liquor flow is maintained at plant production rate which is about 110 GPM; light oil flow is maintained in a ratio to the liquor flow of about 1.25/1 0.

Inlet pressure of the weak liquor feed is about 90 psig, whereas the light oil inlet pressure is 155 psig.

SLIDE #10 - Reactor Operating Data:

This slide shows the operating conditions at the Reactor unit as it is operated in conjunction with the Extractor unit.

The speed of the rotor on this unit is maintained at about 1500 RPM.

The next two slides will show the actual phenol concentration data and operating requirements that are representative of present day operation at Weirton:

SLIDE #11 - Typical process values.

Kindly note the various values, particularly the carbolate strength; this is actual production concentration without evaporation.

SLIDE #12 - Process, utility and labor requirements.

This slide is a tabulation of the various operating requirements comprising caustic, electric power, steam, water and air. The direct labour requirements amount to one man per shift, with the plant laboratory performing the various phenol determinations as part of its routine. Item 7 is an attempt to specify anticipated maintenance, and is based on our experience to date.

In connection with the various process requirements, we should like to point out that the solvent hold-up for the entire system, comprising extractors, pump tanks, piping, etc. is less than 1000 gals. This volume is less than 2% of the total solvent hold-up (65,000 gals.) required for a static-type plant of comparable liquor handling capacity and efficiency, a rather startling comparison.

The solvent, or light oil, loss in this type of dephenolization plant is pratically negligible; the principal points of losses being the very small amount from the pump tank vents and any pump packing leakage. The solvent dissolved in the dephenolized liquor will be returned to the gas stream following distillation in the ammonia still.

At this time we would like to review a few of the difficulties experienced in the initial operations which, I am sure, you will agree can be considered normal for all new plant developments.

Without going into the minor plant irregularities, there were two main sources of trouble encountered that seriously affected the operation of the new plant. In their order of importance they were (1) contaminated weak liquor and (2) mechanical seals on the extractors.

It is a fact that the ammoniacal liquor produced in coke plants, which we consider normal liquor, generally contains, in addition to ammonia and phenol, other impurities such as dissolved acid gases and salts, varying amounts of organic materials such as naphthalene, tars, tar oils, and insoluable carbonaceous material.

These components comprising tars and carbonaceous materials constitute a serious detriment to satisfactory phenol plant operations because of emulsification tendencies with system solvent and plugging or fouling of apparatus, necessitating periodic shut-down or by-passing of certain equipment for cleaning purposes.

In our start-up operations, this was exactly the case. Relatively clean liquor brought about an extended run, however, a slug of tar would shut the plant down almost immediately. This is the end effect in a system having an extremely low hold-up, which magnified liquor contamination.

It became apparent that we should do all possible to clarify the feed liquor to promote maximum operating time and avoid emulsification and plugging difficulties.

This was accomplished by pre-washing the raw ammonia liquor with a small stream of dephenolized light oil before the liquor coolers, then subsequently decanting the contaminated oil before feeding the liquor to the Extractor unit. The tars, naphthalene and carbonaceous materials in the liquor are either soluble in, or affected by, a specific gravity change whereby all materials remain in the light oil wash layer.

This contaminated oil wash layer is periodically drained and processed through the coke plant for recovery of the light oil.

The normal dilution rate of fresh light oil for purpose of maintaining quality of system solvent is 2000 gals. per day. This 2000 gals. per day is that volume of dephenolized system solvent used for clarification of the weak liquor.

Mechanical seal difficulties were troublesome during the initial operations. Primarily this was due to heat checking of the hard face seals because of the poor lubricating qualities of system solvent.

Some experimentation was necessary to select better materials of construction and it was found that Ni-Resist had superior all around qualities and therefore was adopted for our work. In addition, our operating experience with mechanical seals revealed the necessity for correcting the hydraulic balance for higher pressure values than originally contemplated.

Generally speaking, this completes our paper on commercial dephenolization of ammoniacal liquor by centrifugal extraction as it is carried out daily at the Weirton plant. It undoubtedly will be of interest, that at this moment we are completing engineering for a second installation of this type for the Harriet plant of our associate Semet-Solvay Division. The plant will have a capacity somewhat greater than the Weirton installation, approximately 250,000 gals/day, and will incorporate all the improvements developed at Weirton. It is expected that this plant will be in operation during the latter half of 1958.

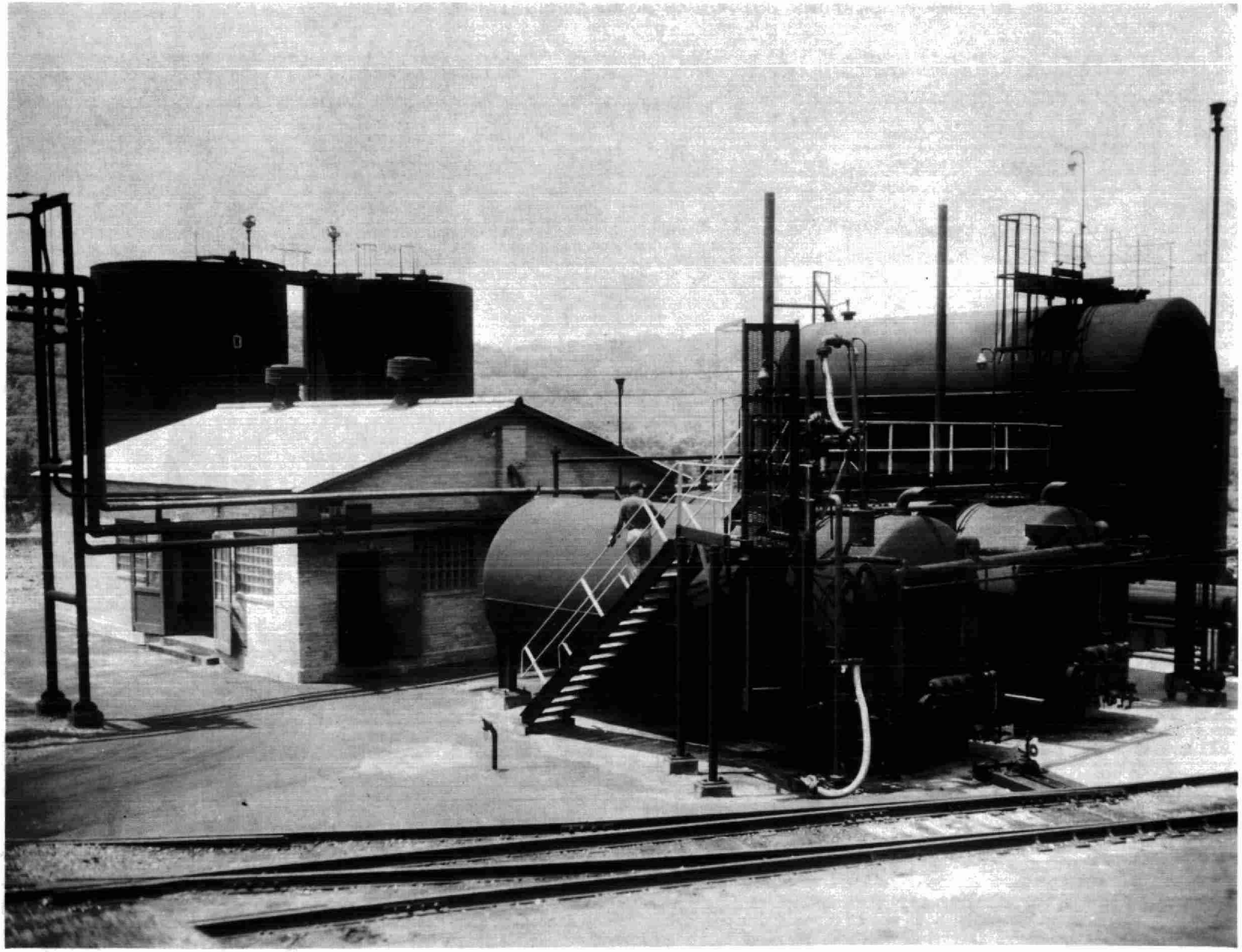


FIGURE 1 EXTERIOR VIEW OF WEIRTON STEEL COMPANY PLANT

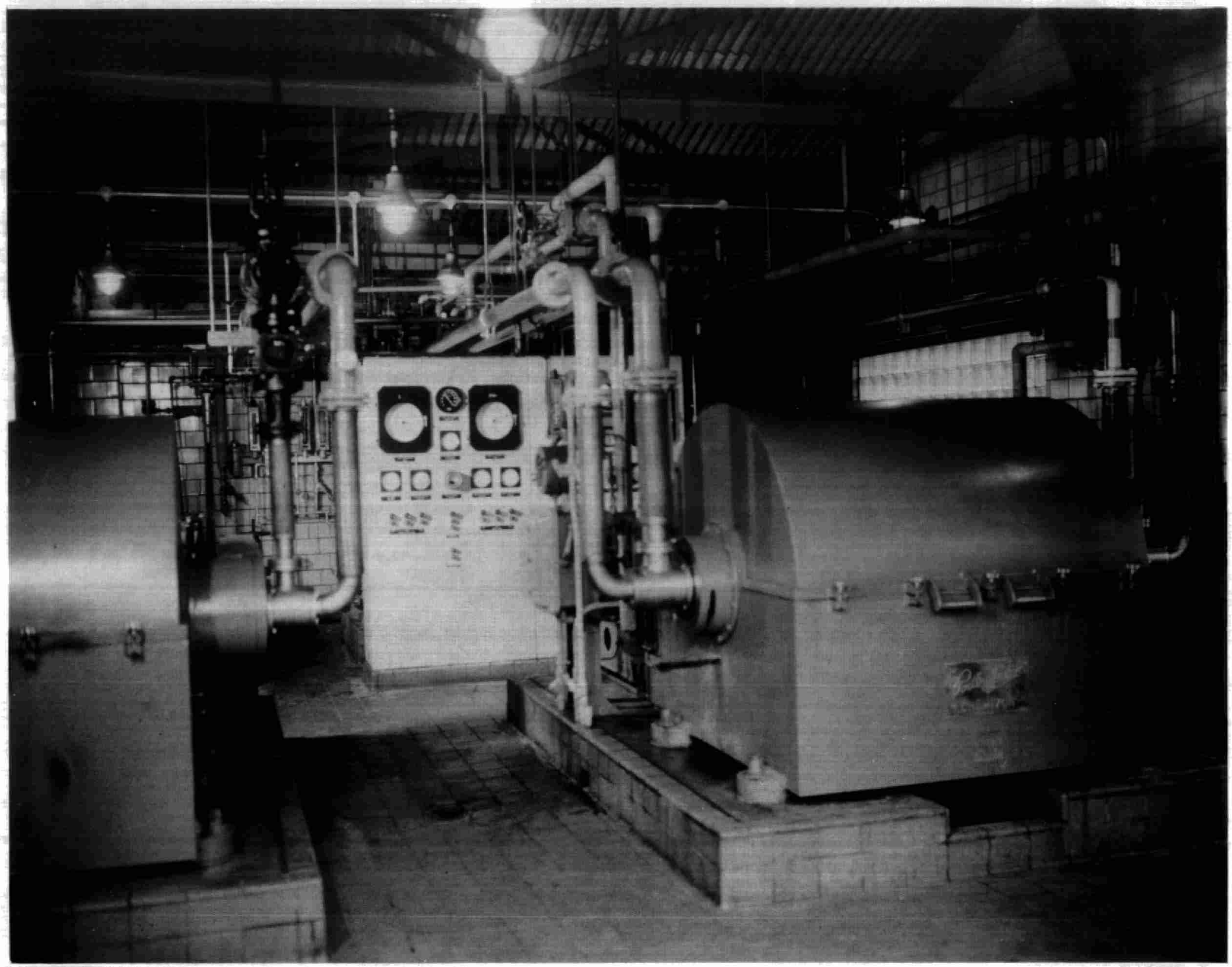


FIGURE 2–INTERIOR VIEW OF EXTRACTOR BUILDING

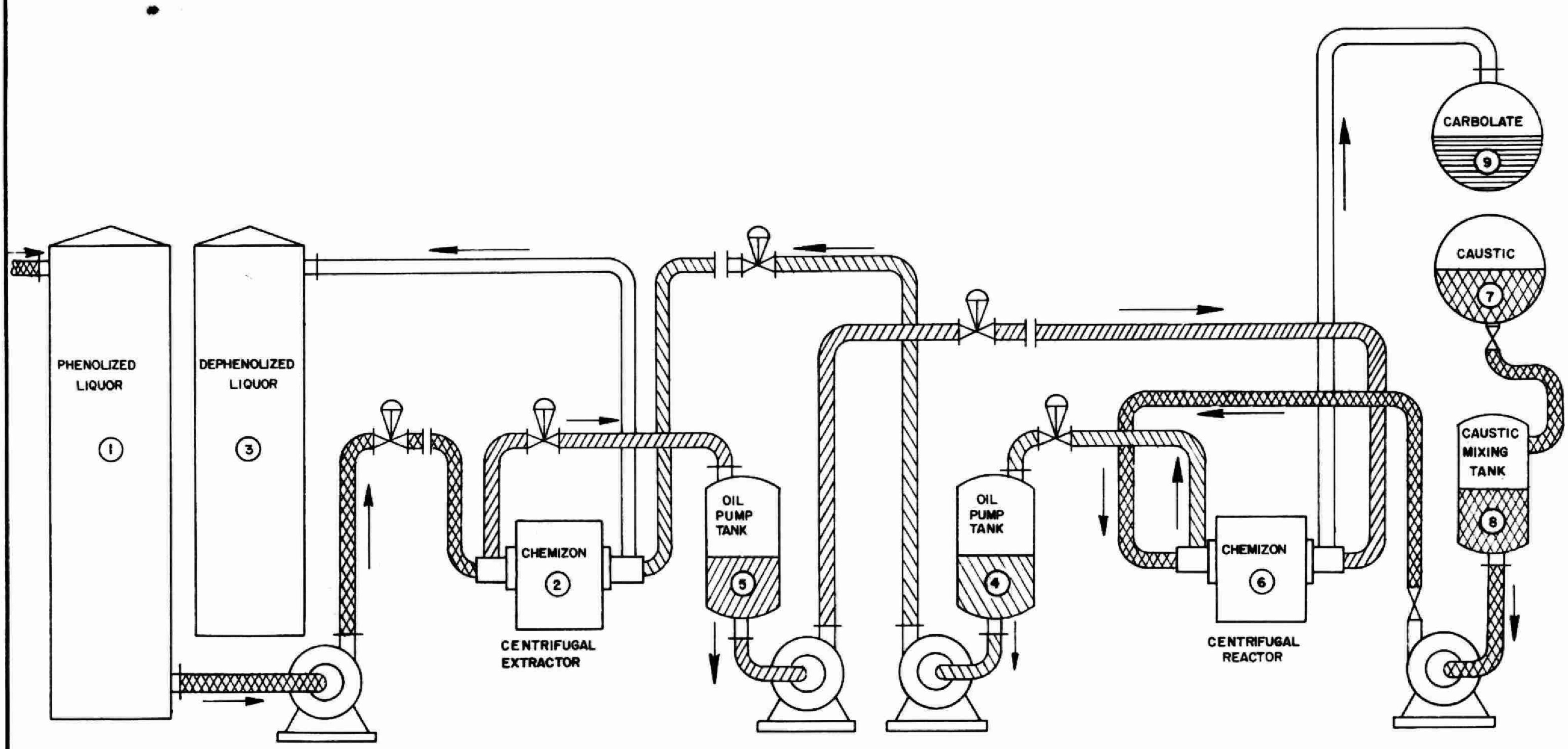


FIGURE 3- FLOW DIAGRAM OF PHENOL REMOVAL PROCESS

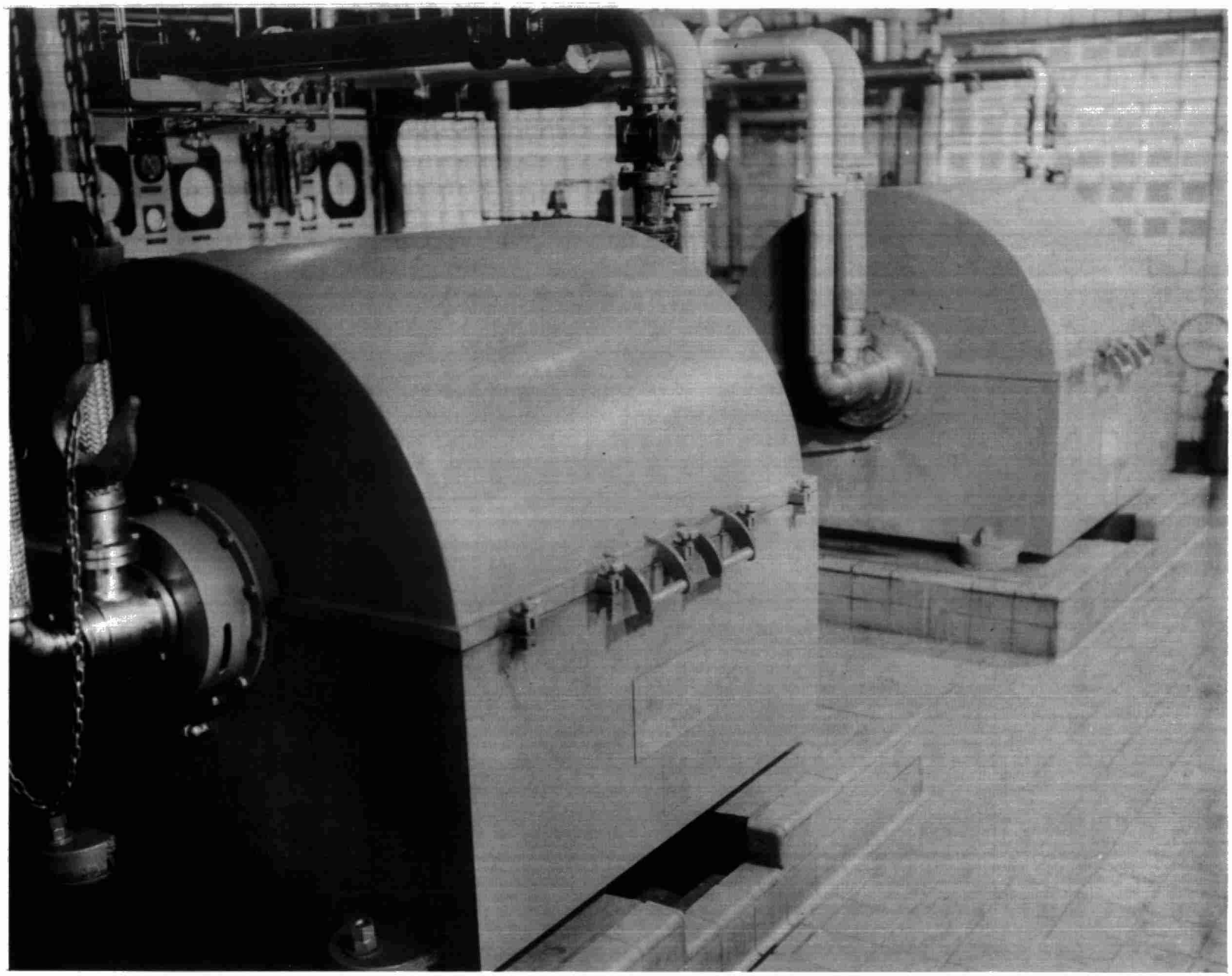


FIGURE 4 FRONT DIAGONAL VIEW OF EXTRACTORS

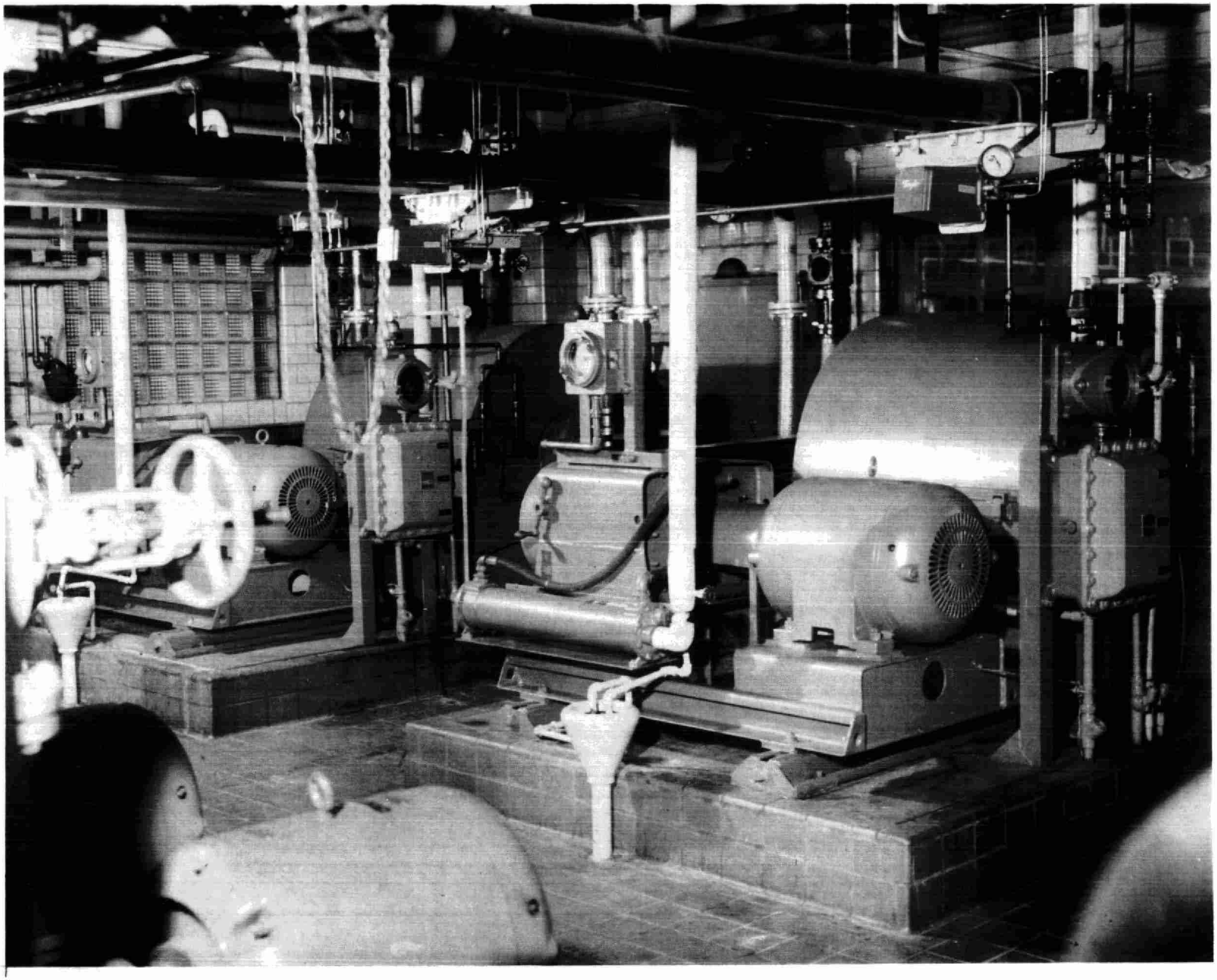


FIGURE 5 REAR VIEW OF EXTRACTORS

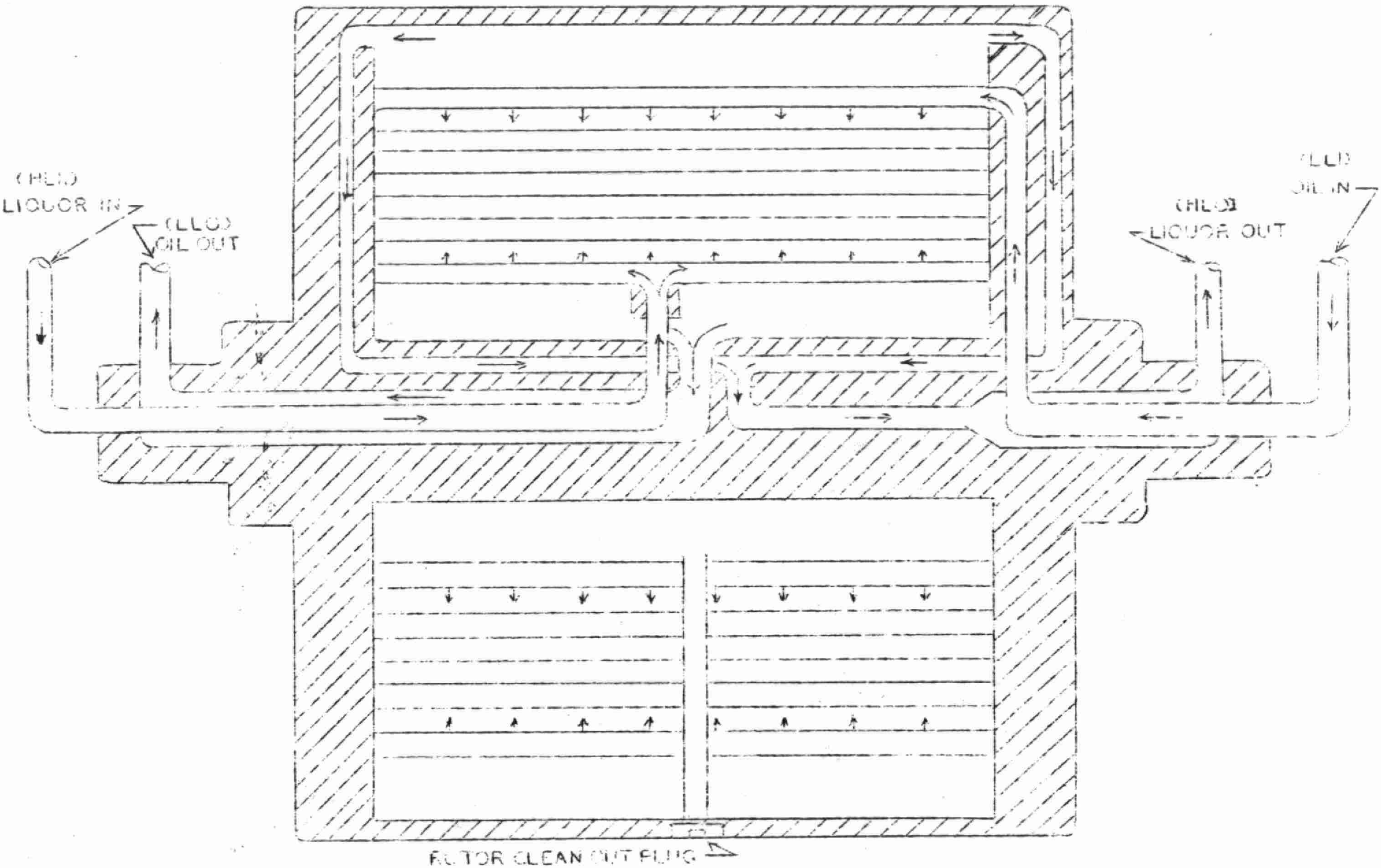


FIGURE 6 – EXTRACTOR FLOW DIAGRAM

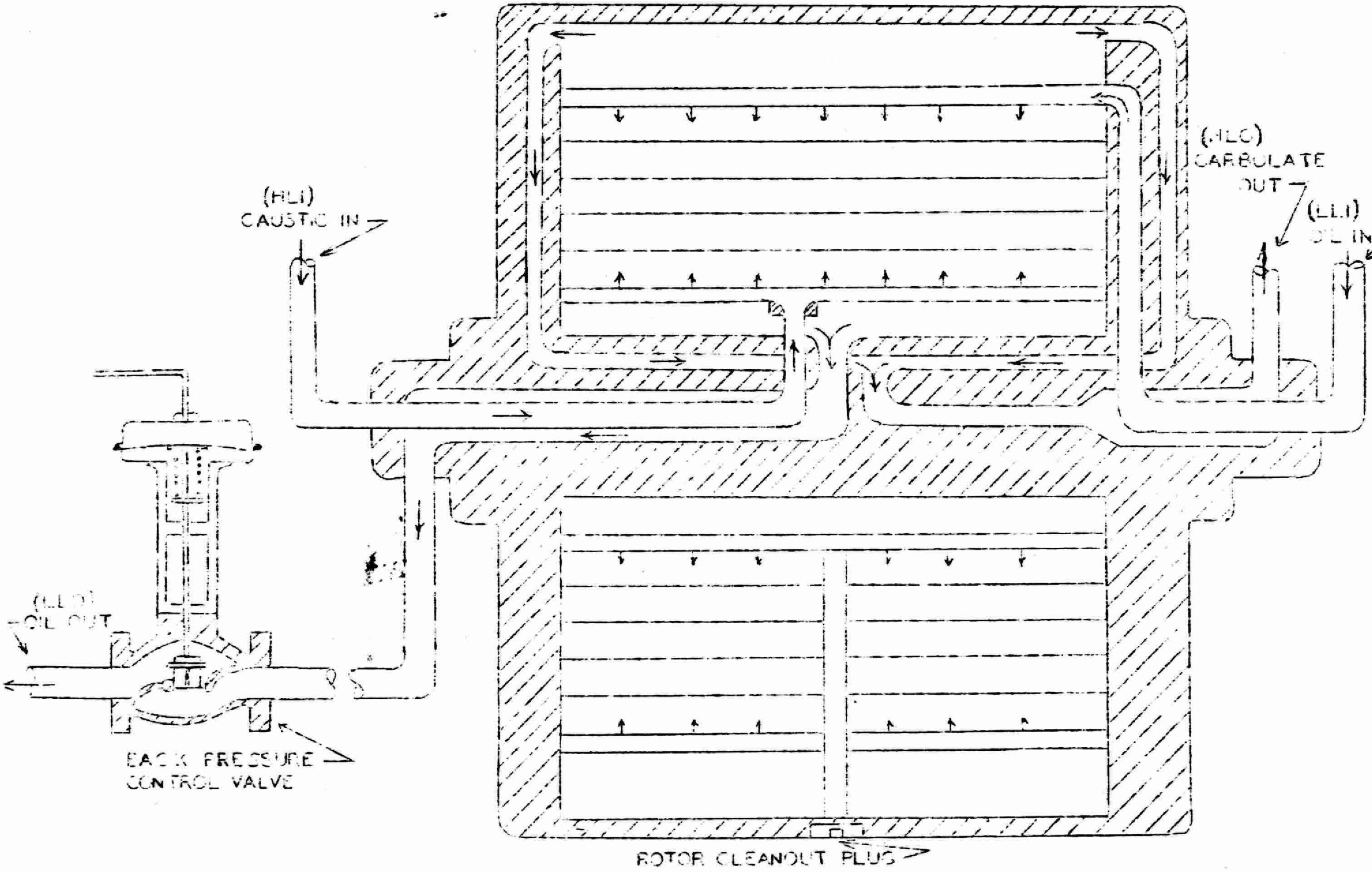


FIGURE 7 - REACTOR FLOW DIAGRAM

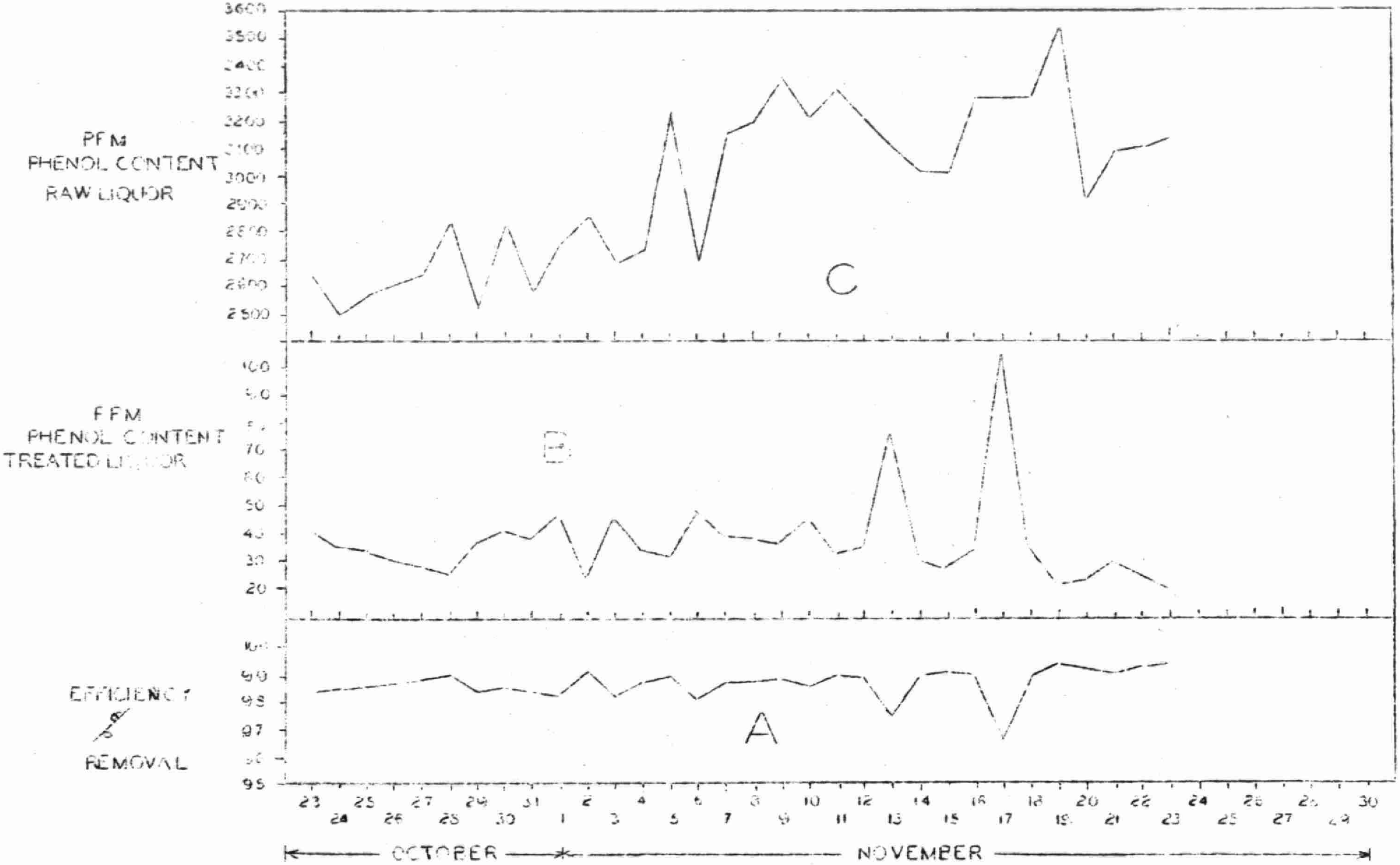


FIGURE 3 - GRAPH OF OPERATING DATA — PHENOL PLANT — WEIRTON STEEL CO

- TABLE I -

PHENOL PLANT
OPERATING DATA

EXTRACTOR

Speed	-RPM	1750
Weak Liquor Before Coolers	-Temperature °C	65
Weak Liquor After Cooler	-Temperature °C	40
Weak Liquor Flow Rate	-GPM	110
Light Oil Flow Rate	-GPM	137
Ratio-Light Oil/Liquor	-	1-1/4/1.0
Weak Liquor Inlet Pressure	-PSIG	90
Light Oil Inlet Pressure	-PSIG	155
Light Oil Outlet Pressure	-PSIG	90
Motor Amperes	-	24
Lubrication Oil Pressure	-PSIG	32

- TABLE 2 -

PHENOL PLANT
OPERATING DATA

REACTOR

Speed	-RPM	1500
Light Oil Flow Rate	-GPM	150
Light Oil Inlet Pressure	-PSIG	185
Light Oil Outlet Pressure	-PSIG	70
Light Oil Outlet Temperature	-°C	44
Weak Caustic Inlet Pressure	-PSIG	70
Strong Caustic Inlet Pressure	-PSIG	2
Weak Caustic Flow Rate	-GPH	21
Strong Caustic Flow Rate	-GPH	40
Motor Amperes	-	24
Lubrication Oil Pressure	-PSIG	45

- TABLE 3 -

PHENOL PLANT
OPERATING DATA

TYPICAL PROCESS VALUES FOR PRESENT OPERATIONS

Phenolized Liquor	PPM Phenol	2520
Dephenolized Liquor	PPM Phenol	36
Removal Efficiency	%	98.6
Phenolized Oil	PPM Phenol	1860
Dephenolized Oil	PPM Phenol	52
Oil to Liquor Feed Ratio		1.3/1.0
Carbolate		
Total Alkalinity (Calculated as NaOH)	GPL	240
Tar Acid Content (wet)	%	36

- TABLE 4 -

PHENOL PLANT
OPERATING DATA

PROCESS, UTILITY AND LABOR REQUIREMENTS

1-Caustic-1 lb./lb. Phenol
2-Electric power-100 kilowatts
3-Steam-None required for processing or concentration.
    Steam is used only for steam tracing and tank warming in winter.
4-Water-Small quantity for process requirements-Approximately 40 gals./hr. for caustic solution (city water).
    3/4 gal. of mill water/gal. weak liquor treated, for liquor cooling; yearly average.
    This quantity is required for any process since weak liquor from Flushing Liquor system must be cooled.
5-Air -Instrument air only.
6-Labor-One man per shift.
7-Normal Operating Maintenance-
    From our experience to date, we feel that maintenance will comprise the following:
        (a) Normal pump packing.
        (b) Mechanical seals-should be good for one year.
        (c) Machine cleaning-Cleaning required once every two months. Two machines require 6 hours time.

APPROACH TO THE TREATMENT OF REFINERY WASTES

- by -

Dr. J.D. Frame

Assistant to Vice-President
Cities Service Research Co.
New York City, U. S. A.

The approach to the treatment of refinery wastes is to a large extent determined by the philosophy of management. Most everyone will agree, in principle, that water pollution should be controlled. However, the development of adequate controls which can best serve the interests of both the individual user and the general public is difficult. In some areas little effort has been made to establish any type of controls, in others, such as the Province of Ontario, great advancements have been made in the restoration and conservation of a valuable natural resource. This has been accomplished through the timely and intelligent administration of the Ontario Water Resources Commission and its affiliated groups. However, the existence of a central agency for pollution control does not, in effect, relieve an individual user of any of the responsibility for maintaining the receiving waters in a condition fit for beneficial use by others. Thus, I firmly believe that, in the cause of industry, management must recognize and accept the responsibility. This, the management of Cities Service Oil Co., Ltd. and Cities Service Company as a whole has done. As a result, we are currently continuing at all five of our refineries, waste control programs which are specifically designed to permit each refinery to develop and expand its waste treatment facilities in light of present and anticipated future conditions.

I feel sure that some of you have heard that Cities Service Oil Co., Ltd. is planning to install a rather unique and very complete wastes treatment plant at its new refinery in Bronte, Ontario. This is true and is the result of the expressed wishes of management that the effluent from this refinery will in no way interfere with the interests of its neighbours or of the public in general.

In closing I wish to ask a favor of you. To date, the planning on the treatment facilities has not been finalized nor obviously do we have any operating data. For these reasons it would be greatly appreciated if you would not at this time raise any questions with respect to the planning at this refinery. However, the company would like to extend an invitation to all, who may be interested, to visit the refinery, following the dedication.

THE EFFECT OF PULP AND PAPER MILL WASTES ON AQUATIC LIFE

- by -

Willis M. Van Horn

The Institute of Paper Chemistry
Appleton, Wisconsin

On the North American Continent, and, I suspect on others as well, we are faced with a real problem of conservation particularly as it relates to wood and water. Water, as we all know is, quantity wise, a stable resource. That is, to say, there is just so much of it on the face of the earth, and while man may alter its position or quality, he cannot affect the quantity. By now, it is a somewhat well-worn cliche to say that as our population grows, and as the effects of this population growth is manifested on the quality of our surface waters, it will become increasingly important to us to learn how to manage the water resource so that it can meet the increased demands placed upon it.

The wood resource, on the other hand, is a renewable resource, as is the case of anything that reproduces by natural means, and grows. The amount of wood that can be produced on the continent will be dependent upon how skillfully we can manage our woodlands in the light of present knowledge and, also, in the light of new discoveries as yet unmade.

The pulp and paper industry has not, as yet, discovered how to make pulp and paper out of this wood without using large quantities of water. This industry is certainly in a unique, if paradoxical, position. It manages large wooded areas for the production of wood and in so doing provides an environment that equalizes the run-off of precipitation, or in other words, its watersheds not only produce wood, they also aid in stabilizing the water supply.

But when this water and wood come together in a pulp mill the wood is reduced to fiber, and the nonfibrous part of the wood--up to about 50% of the total wood volume in some cases--may be added to the water and returned to the stream. Added to this may be certain chemical compounds which are incidental to the pulping and papermaking process.

This brings the industry face to face with one of its most pressing problems, namely, how to utilize the wood resource without seriously harming the water resources. Before we can begin to arrive at the answer to this question we need to know more precisely how and to what extent pulp and paper waste waters affect the stream life.

It will be useful here to consider for a moment what we mean by aquatic life. Much of the concern of biologists is directed to the welfare of fish themselves, but the water life complex involves many other forms. Perhaps the lowest form in this complex are the bacteria, algae, and single-celled animals known as protozoans. The bacteria and protozoans act as scavengers, whereas the algae, being for the most part chlorophyll bearing, behave much the same as any other plant. For our purposes here we can consider that the next higher forms are the plankton organisms. These are both plant and animal, but have the common characteristic of not having well-developed locomotor facilities and are therefore at the mercy of water currents. Another important group for consideration are the so-called bottom dwellers, such as molluscs, aquatic insect larvae and certain higher forms including the crayfish, etc. Then, of course, there are fish.

The important point to remember about the aquatic life complex are that its units are inter-dependent. Each group, with the possible exception of the algae, feed on one another, the fish for example, may feed on plankton, insect larvae, and other higher forms.

Nature being what it is, all these forms may exist in the same environment, competing with one another for survival. It is this competition that operates to keep the number of any one species more or less stabilized at a level commensurate with the natural character of the environment. If man does something, such as adding a pollutant, to the aquatic environment, he introduces a new condition and this may upset the whole complex balance which nature, if left alone, would maintain. The purpose of this discussion is to examine how this natural balance can be upset when pulp and/or paper mill wastes are added to a stream.

Generally speaking any type of waste material may affect the stream in one or more of three different ways. It may contain, for example, materials which are toxic or poisonous. When such materials are present in high enough amounts, the whole fauna may be destroyed. Another way a waste may affect a stream is by depressing dissolved oxygen concentrations of water. Most materials of this type are organic in nature, containing substances which are available to bacteria only. Their presence stimulates the reproduction and growth of these forms to the point where their combined oxygen requirements may exceed the available supply. Incidentally the oxygen these microorganisms require in the process of stabilizing the waste is called Biochemical Oxygen Demand (B.O.D.). Of all pulp and paper mill pollution problems, those associated with oxygen balance are the most widespread and the most serious. Finally, a waste may contain inert materials, resistant to breakdown, that maintain their form and substance indefinitely when passed to a stream. Such materials usually settle on the bottom of a waterway, and depending on their amount, may seriously interfere with bottom life even to the point of destroying it.

Our purpose now is to examine waste waters from pulp and paper mills in the light of the three pollutional possibilities which we have just mentioned. It should be borne in mind that each stream and each mill varies so widely that this discussion can deal only in generalities.

The Question of Toxicity.

Various studies have been made from time to time on the toxicity of pulp and paper mill wastes. Among the first of these were those of Dr. A. E. Cole. He worked on both spent sulfite liquor and kraft pulping wastes. He concluded that under normal circumstances spent sulfite liquor created no problem of toxicity. More recently this question has been reopened in the State of Washington where evidence has been informally presented indicated that oysters may be affected by relatively small concentrations of spent sulfite liquor. In this case it seems apparent that more evidence must be developed before any definite conclusions can be drawn.

Many workers, both in Sweden and in North America have studied the potentially toxic aspects of draft waste waters. The results from our laboratory are shown in Table I.

TABLE I
THE MINIMUM LETHAL CONCENTRATION OF KRAFT PULP WASTE COMPONENTS AFFECTING MINNOWS, DAPHNIA AND TWO KINDS OF AQUATIC INSECT LARVAE

	Minimum Lethal Concentration, p.p.m			
	Minnows	Daphnia	May fly[1] larvae	Chironomus larvae
Sodium hydroxide	100.0	100.0	100.0	700.0
Sodium sulphide	3.0	10.0	1.0	1000.0
Hydrogen sulphide	1.0	1.0	1.0	750.0
Methyl Mercaptan	0.5	1.0	1.0	50.0
Crude sulphate soap	5.0	5.0	10.0	50.0
Sodium salt of resin acid fraction of crude sulphate soap	1.0	3.0		
Sodium salt of fatty acid fraction of crude sulphate soap	5.0	1.0		

[1] May fly larvae used were of the genera Blasturus and Leptophlebia.

It will be noted that those kraft waste components having the highest potentially toxic properties are sodium sulfide, hydrogen sulfide, methyl mercaptan, sulfate soap, and the components of such soap.

Several years ago, in co-operation with the National Council for Stream Improvement, we made an extensive study of these components in a number of kraft mill waste waters. At the same time we determined the dilution ratio between the volume of sewer discharge as compared to river discharge. The results from the "worst" mill are contained in Table II.

Once having the actual concentrations in the waste, we divided these values by the dilution ratio, thus calculating the probable concentration in the river after total dilution. Comparing these values with the lethal concentrations in Table I, it was concluded that, under normal conditions, assuming that the mill is operated with reasonable care, there need be no toxicity hazard resulting from a kraft mill operation. It should be noted that at the time these studies were made the mills under study did not have the modern washing and other liquor conservation facilities characteristic of modern mills.

The other area of the industry where a potential toxicity problem may be encountered is in the manufacture of paper. Depending on the type of furnish used, some machines have a tendency to develop bacterial slimes. Such slimes interfere with sheet formation and may

TABLE II

THE RESULTS OF WASTE WATER ANALYSES OF A TYPICAL NORTHERN KRAFT MILL

		Parts Per Million				
Sample No.	River Dilution Ratio[1]	Sulphides	Mercaptans	Resin and Soap	Sodium Hydroxide	pH
1	170	0.7	1.5	5.0	6.6	8.6
2	166	0.6	0.7	5.5	8.0	8.8
3	178	1.5	4.1	18.0	61.4	9.9
4	218	1.6	1.8	8.0	24.2	9.4
5	185	1.0	1.2	5.0	12.0	9.0
6	193	0.2	1.9	5.0	0.0	7.8
7	275	18.4	12.0	18.0	114.0	10.0
8	232	0.5	2.5	3.0	6.6	8.7
9	224	0.2	0.7	3.0	0.0	8.2
10	138	0.4	0.9	2.0	0.0	8.2
11	142	0.9	1.6	3.0	0.0	8.2
12	126	0.6	1.0	3.0	0.0	8.1
13	123	0.8	1.6	3.0	14.7	8.7
14	193	0.0	2.7	5.0	10.6	8.7
15	173	0.2	1.4	5.0	0.0	8.3
16	191	0.2	0.9	5.0	14.7	8.8
17	173	0.2	1.2	2.0	0.0	7.6
18	176	0.0	1.1	5.0	0.0	7.9
19	166	0.0	1.2	3.0	0.0	7.9
20	177	0.2	1.1	3.0	0.0	7.7
21	153	0.2	1.1	3.0	0.0	8.4
22	152	0.0	0.8	3.0	0.0	8.1
23	157	0.0	0.6	2.0	0.0	8.3
24	144	0.3	1.0	2.0	2.6	8.5
25	156	2.1	1.9	3.0	13.3	8.9
26	161	88.4	15.8	18.0	391.0	10.5
27	113	0.4	1.6	3.0	4.0	8.5
28	103	0.3	1.7	3.0	17.3	9.0
29	96	0.0	3.1	5.1	9.3	8.7
30	94	2.8	3.3	8.0	21.4	8.8
31	94	25.8	8.1	18.0	115.0	9.4
32	134	0.4	1.0	3.0	114.0	10.7
33	136	3.6	5.1	5.0	13.7	8.9
34	127	2.8	7.2	3.0	9.4	8.8
35	109	1.3	0.9	5.0	0.2	8.5

---

[1] River flow regulated for power production.

cause holes and discoloration in the sheet. To remedy this situation various biocides are added to the machine water system. We have conducted extensive bioassay tests on many of these agents. One of these is phenylmercuric acetate which has a minimal lethal concentration of 0.02 p.p.m., another is sodium pentachlorophenate with a minimum lethal concentration of 0.2 p.p.m. Outside of chlorine, the toxic action of which is quickly dissipated in a machine system, most agents now in use are either one of these two agents, or combinations of them. They are usually used in a machine system in concentrations up to 5 p.p.m. However, now-a-days paper machines are operated so that there is a minimum of water loss to the sewer and this serves also to minimize the loss of biocides. The author has yet to find a case, in the United States, where the use of slime biocides constitutes a hazard to aquatic life.

The Question of Biochemical Oxygen Demand.

It was stated above that the problem of maintaining an adequate oxygen balance in the receiving streams is the most serious waste disposal problem facing the pulp and paper industry. It may be of interest to examine, for a moment, the B.O.D. loading of the various pulp and paper operations. If no attempt is made at recovery, the spent liquor resulting from the manufacture of a ton of sulfite pulp will require about 500 pounds of oxygen from the stream. Bleaching will add up to 40 pounds additional in any type of pulp. Unbleached kraft pulp has a B.O.D. loading of from 20 to 40 pounds per ton of pulp produced. Neutral sulfite semichemical pulp averages around 200 pounds of B.O.D. per ton produced. Groundwood pulp requires about 5 pounds of B.O.D. per ton. This is true also for the manufacture of paper.

It is interesting to note the biological changes which may take place in a stream in the face of an unbalanced oxygen situation. It will be recalled that the complex consists of bacteria, plankton, bottom dwelling forms, such as aquatic insect larvae and minnows and fish.

When the oxygen balance of a stream is disturbed the first forms to disappear are certain aquatic insect larvae, especially certain May and Caddis fly larvae. If more serious conditions prevail the midge larvae are destroyed. In extreme cases of pollution the only forms remaining may be the rattailed maggot (an air breather) and tubifex worms.

A most interesting observation is the way in which game fish may respond to this population change. Stomach content analyses indicate that in clean water such fish feed mainly on Caddis, May and stonefly larvae. Some midge larvae are also taken. When these forms disappear there is a tendency for the game fish to search out new areas where such forms do occur. Certain so-called rough fish, such as suckers and buffalo, being in part at least, vegetarian, may remain in unbalanced streams indefinitely.

These bottom dwelling forms are quite widely used as indicator organisms. Biologists generally agree that if there is a wide spectrum of aquatic insect larvae, for example, in a stream, then that stream may be considered clean. If the population shifts to predominantly midge larvae, the stream is considered unbalanced, or semipolluted. Finally if the population is almost wholly tubifex worms the stream is said to be polluted.

There are, of course, exceptions to this general rule. The writer has studied many unpolluted streams, particularly in the southeastern part of the United States where the normal, unpolluted population is predominantly midge larvae. In such cases it must be concluded that some environmental factor, other than oxygen unbalance, is the cause of the population shift. It is in such instances that a study of a waterway before the mill is built is so important.

In any event it is possible, by studying the nature of an aquatic population, to gage the general condition of a stream as related to the oxygen resources of that stream. The method is of value not only in measuring stream pollution, but also, stream improvement as a result of remedial treatment operations.

The Question of Inert Solids.

For the most part this area of stream economy as related to the pulp and paper industry is less troublesome today than it was in former years. In times past the most serious problem was caused by the passage of wasted or lost cellulose fibers. Such fibers undergo decomposition very slowly and would form, in some cases, extensive deposits on the bottom of the stream. When this happened a normal bottom fauna could not develop and the fish-fish food relations was seriously disrupted.

In modern pulp and paper mills a very serious effort has been made, over the past twenty years, to install equipment designed to retain the fiber in the mill system. This equipment is usually in the form of save-alls, which may be of the vacuum type, gravity settling or flotation. Table III shows the results of a twenty-year effort on the part of 69 pulp and paper mills in Wisconsin to reduce fiber loss. It will be noted that in all cases this effort has been significantly successful. It should also be noted that this program has resulted from close co-operation between the Wisconsin Committee on Water Pollution and the pulp and paper industry of that State. Nor is this situation unique to Wisconsin. Similar efforts are going forward through the entire industry both in Canada and the United States.

Summary.

This has been a generalized discussion of the effects of pulp and paper mill wastes on aquatic life. Biological studies of the type described are useful in two ways. They help to define and evaluate pollution problems, and they are also useful in measuring stream improvement after remedial measures are installed. As was stated in the beginning the use of biological measurements will be of real value, in the years that lie ahead, in enabling the pulp and paper industry to learn how to utilize the wood resource without harming the water resource.

TABLE III

AVERAGE YEARLY FIBER LOSS (% OF TOTAL PRODUCTION) OF 69 PULP AND PAPER MILLS 1937-56 (INCLUSIVE)

TYPE OF MILL (NUMBER OF MILLS IN EACH CATEGORY IN PARENTHESIS)

YEAR	BOOK (9)	TISSUE (9)	WRAPPING (8)	BOND (6)	GLASSINE (3)	RAG AND DEINK (5)	BOARD (1)	KRAFT PULP (5)	SULPHITE PULP (15)	GROUND-WOOD PULP (5)	SEMICHEM (3)
1937	1.4	2.2	1.8	1.6	3.1	14.1	1.0	2.5	2.3	2.3	
1938	1.3	2.6	2.8	2.2	4.1	27.4	1.2	2.9	2.2	2.9	
1940	1.1	2.6	2.5	2.0	2.3	15.9	1.2	2.8	2.6	3.0	
1941	1.2	2.9	2.4	1.6	3.9	9.9	0.9	1.8	2.5	2.6	
1942	0.7	2.0	2.2	1.3	3.4	8.3	-	2.1	1.9	0.3	
1943	0.7	2.0	1.5	1.3	2.4	10.5	1.0	2.4	2.3	0.5	
1944	0.8	2.5	2.4	1.5	2.0	7.6	0.8	2.0	2.5	0.5	
1945	0.8	4.0	1.6	1.2	2.9	8.4	0.8	2.0	1.9	1.1	
1946	0.9	1.5	1.6	2.8	1.6	6.1	0.5	3.1	2.0	0.6	
1947	0.9	1.6	0.7	1.7	2.9	8.9	0.4	2.5	2.0	0.5	
1948	0.8	1.7	1.2	1.4	2.8	7.8	0.9	2.5	2.4	0.3	
1949	0.9	1.3	1.3	1.5	2.3	5.9	0.7	1.3	1.8	0.4	2.1
1950	0.6	0.9	1.3	1.0	3.5	8.7	0.4	1.3	1.9	1.3	4.5
1951	0.7	1.6	1.2	0.6	0.8	5.7	0.6	1.6	1.7	0.7	1.6
1952	0.8	1.1	1.5	0.5	1.6	5.4	0.5	1.5	1.3	0.6	0.7
1953	1.0	2.2	1.4	0.7	1.9	4.2	0.5	1.3	1.6	0.2	0.7
1954	1.2	1.2	1.3	0.5	2.0	1.9	0.6	1.4	1.6	0.6	0.5
1955	0.9	1.0	1.5	0.7	1.5	2.5	0.7	0.9	1.3	0.2	1.4
1956	0.8	0.9	1.1	1.0	1.6	2.2	0.8	1.1	1.3	0.5	0.5
1957	0.8	1.0	0.9	1.1	1.4	1.7	1.0	1.2	1.5	0.5	0.8

STREAM IMPROVEMENT THROUGH SPRAY DISPOSAL OF SULPHITE LIQUOR AT THE KIMBERLY-CLARK CORPORATION, NIAGARA, WISCONSIN MILL

- by -

R. M. Billings

Kimberly Clark Corp.,
Neenah, Wisconsin, U. S. A.

For over 100 miles the Menominee River forms a boundary line between Northeastern Wisconsin and the Upper Penninsula of Michigan. At Niagara, Wisconsin, six miles southeast of Iron Mountain, Michigan, Kimberly-Clark has been producing groundwood pulp since 1898 and sulphite pulp since 1901. This stretch of the Menominee flows through rugged country, well wooded and wild even today. Jagged bluffs and rock outcroppings lend further beauty to the region. Because of the ruggedness of the country and the nature of the soil, much of the area is unsuitable for farming. The mill was located at the present site because of the presence of Quinnesec Falls which furnished the much needed power for a pulp mill.

For several decades after the mill was established, no pollution problem made itself evident. The river ran for miles through relatively unsettled country. Numerous falls and rapids together with long stretches of fast moving water made the Menominee a truly working stream capable of absorbing sufficient oxygen to assimilate all waste material both natural and industrial which found its way into it.

As the years went by, however, the population of the area increased. Cities expanded and new industries sprang up, all of which depended upon the river for the ultimate disposal of their waste. This increased population and industrial activity was accompanied by an increasing demand for power. As a result, power dams were built at intervals along the Menominee and motionless pools behind dams appeared where formerly there had been long stretches of moving water. Thus not only was the oxygen-demanding load of the Menominee very markedly increased but its capacity to assimilate that load was markedly reduced. Added to this was the growing awareness that unless the use of the natural resource water was carefully controlled it might not be utilized to provide "the greatest good for the greatest number of people". The Menominee River was a case in point. It was agreed that it was and should be a working river and it was likewise generally agreed that in respect to its oxygen load, it was overworked.

Accordingly, in the present decade, the regulatory bodies of both Michigan and Wisconsin issued a series of orders to cities and industries on the river designed to reduce the waste loading of the Menominee to bring it back to a satisfactory condition. The orders specifically issued by Wisconsin to the Kimberly-Clark Corporation, Niagara Mill required that we take the necessary steps and make the necessary installations by December 31, 1956 to "reduce the spent sulphite liquor pollution of the Menominee River to prevent the occurrence of objectionable conditions".

The pollutional characteristics of spent sulphite liquor are, of course, very well known. The material exhibits no toxic or bacterial properties whatsoever to human beings or to fish or to other marine life but it uses up oxygen at a rate that can adversely affect fish if the stream is thus overloaded. It has been repeatedly demonstrated that fish can be kept alive almost indefinitely in water containing high concentrations of spent sulphite liquor providing that adequate oxygen is present. To keep oxygen present, however, in the presence of spent sulphite liquor is the problem. This material has a very high bio-chemical oxygen demand. For every ton of sulphite manufactured at Niagara, we simultaneously produce spent sulphite liquor containing a five day bio-chemical oxygen demand running between 600 and 700 pounds.

Methods of Compliance.

All available information on methods of reducing pollution of this type was studied in order to meet the state's requirements. Any solution to be satisfactory had to meet two specifications: (1) the system must reduce pollution to "prevent the occurrence of objectionable conditions", and (2) it must be economically feasible, which is a stilted way of saying it must not cost so much that we could no longer afford to keep the Niagara Sulphite Mill in operation. The following were a few of the processes that we considered:

A. Yeast or Specialized Chemicals. We rejected this approach for reasons of limited markets of the products, the very large capital outlay required and the uncertain future of the sulphite process itself.

B. Evaporation and Burning. Again, a very large capital outlay would have been required with a very poor economic return. Investigations of existing installations indicated that extreme difficulty was being experienced to break even in operation with no return on the initial investment.

C. The Use of Spent Sulphite Liquor for Roadbinder. There were not enough roads in the Niagara area to make practical this method of disposal which has been so highly successful at our Company's mill at Kimberly, Wisconsin.

D. Conversion to Ammonia Base Pulping and Its Improved Liquor Evaporation Characteristics. This was a possible solution but the state order did not leave us time enough for the investigations necessary to arrive at a sound decision on so important a matter and the large capital outlay was again a problem. While ammonia base sulphite pulp gives to paper certain characteristics, whether or not these characteristics were best suited to our needs, we were not in a position to decide.

E. Land Disposal of Spent Sulphite Liquor. The study of this general method had been underway for several years in the pilot plant of the Sulphite Pulp Manufacturers Research League of which Kimberly-Clark is a long-time member. We had been following this development with considerable interest and particularly the League's finding that land disposal can be highly effective if the land surface is not loaded with the sulphite solids at too rapid a rate. We decided that a commercial installation of this type would best fill the two requirements stated above even though it would require a substantial capital cost to install and would inevitably cost a steady outflow of operating expenses with no possibility of income to be derived from its use.

Land Disposal

Details of this soil filtration study have been reported by Wisniewski, Wiley and Lueck. (1) Briefly, the Sulphite League had fed spent sulphite liquor at controlled rates to towers one foot in diameter and ten feet high for periods up to 64 weeks. Each tower was filled with a different type of material such as sand, clay or bark. After the initial period of stabilization, it was found that the bio-chemical oxygen demand of the spent liquor was reduced by 50 to 95% in passing through the ten feet of the tower depending upon the rate of feed and the material with which the tower was packed. Best results seemed to be obtained where feeds did not exceed one pound per square yard per day.

When we tackled the job of converting the League's Pilot Plant results into a mill scale commercial operation, we faced the difficult, time-consuming problem of selecting an area that would meet five requirements:

(1) It must have the proper combination of soil characteristics to allow suitable percolation of liquor and the requisite bacterial action.

(2) It must be large enough to accommodate a disposal of 320,000 gallons per day of spent sulphite liquor of a concentration of .625 pounds per gallon to be distributed at no more than one pound of solids per square yard per 24 hrs.

(3) It must be within accessible distance of the mill.

(4) It must cause no unlawful pollution of underground waters.

(5) It must be far enough removed from human habitation to prevent undesirable spray or odors being carried by the wind.

Selection of the Area.

Two areas met the first three requirements. One such area was on the Wisconsin side of the river north of the mill while the second was on the Michigan side of the river approximately one mile east of the mill. To ascertain the probable direction of flow of underground waters, test wells were drilled. Both areas proved to have from 70 to 90 feet of sand of the right type above the water table. Both areas were large enough. Both areas were accessible to the mill. Our first choice was the Wisconsin area but because it was so close to the village well and to an area platted for future community expansion, we decided to consider the area on the Michigan side.

By great luck, a United States Geodedic Survey was in progress in the area. This furnished us with an interesting bit of information. The rock outcropping shown at the bottom of the accompanying map and designated by small crosses was of an entirely different formation from the outcropping extending from the mill in an eastwest band to the river some miles east of it. We had assumed that this rock was all the same geological formation but now with this additional bit of information, we drilled well #7. We went down 180 feet without hitting rock indicating that a valley or ravine filled with sand extended southeast from the proposed spray area. The elevation of the water table in this well at 895*feet above sea level, as compared to the 930 foot elevation of the water table beneath the proposed spray area together with the fact that water tables in existing wells 1/4 mile and 1/2 mile north of the spray area were 950 feet and 952 feet respectively, indicated that flow would be toward the river at this point. The level of the Menominee at the entrance of the small creek shown in the lower right-hand corner of the map is 190 feet below the elevation of the spray area. The Federal geologist for the area concurred with our conclusions. The Michigan site, furthermore, was isolated from any habitation, the land was covered with a few trees and some scrub growth and entirely unsuitable for any other use. For all of these reasons, we selected the Michigan area.

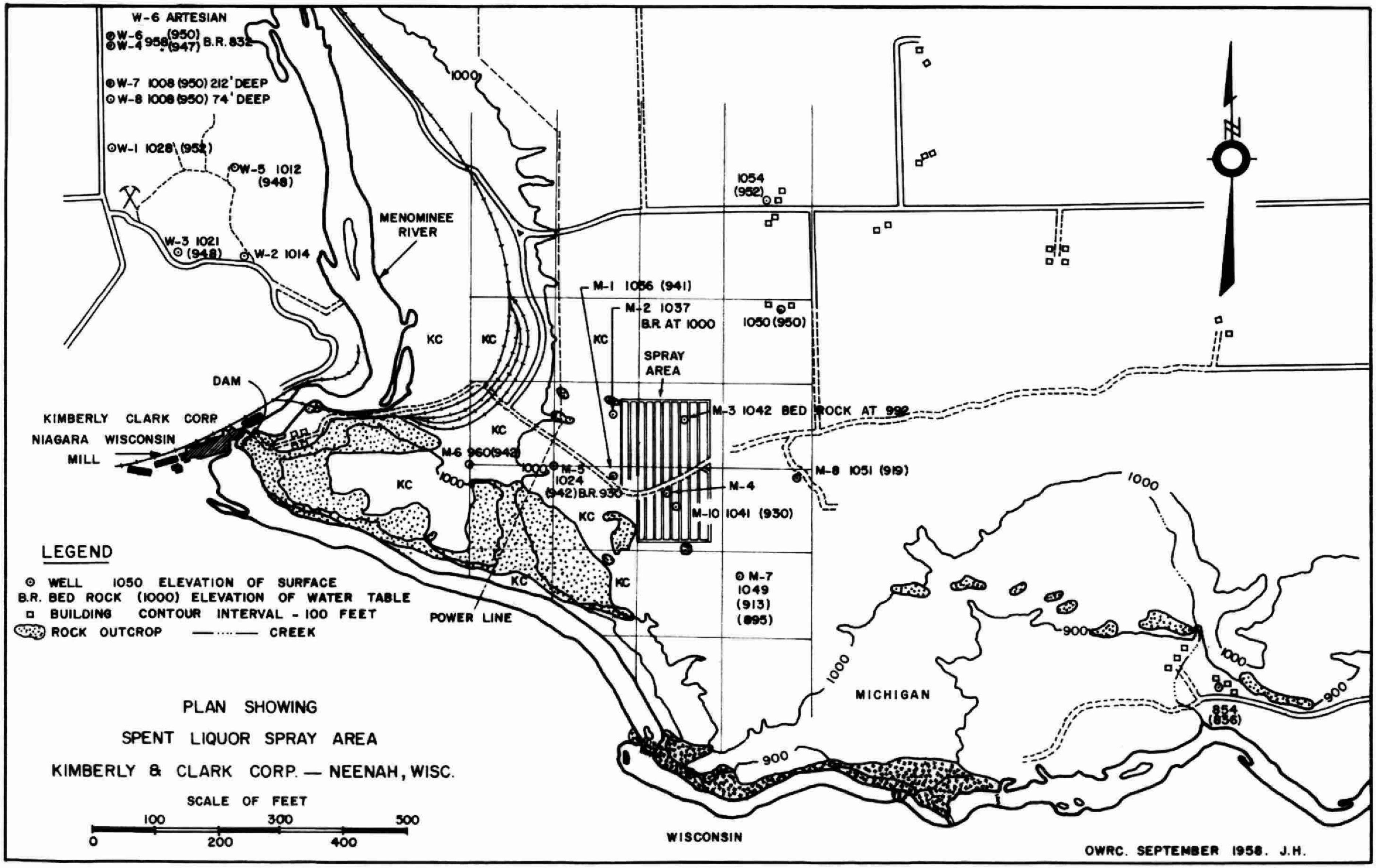
Armed with the above information, we laid our plans before the Michigan Water Resources Commission in Lansing. They were much interested in this new approach to an old problem and co-operated closely with us in all subsequent developments. Kimberly-Clark filed a formal request for new water use -- in this case, the use of underground water for disposal. The commission issued an order permitting the installation, limiting the disposal to a maximum 320,000 gallons per 24 hours, and specifying that "the spray system shall be regulated and controlled so as to prevent unlawful pollution of underground waters". It further required that existing wells on the disposal site be maintained and used for observation of the conditions and elevation of underground water, and that samples should be taken at regular intervals and reports issued to the Commission on May 1, July 1 and October 1 of each year.

Construction.

Construction started in the fall of 1955 with installation of a 60,000 gallon surge tank for spent sulphite liquor. The necessary piping and pumps were installed in the mill to collect sulphite liquor from the blowpits and pump it to the surge tank. A four inch stainless steel line 1,150 feet long was then run from the mill, across the bridge to the Michigan side where a 6,000 gallon loading tank was installed. This was necessary because the bridge crossing the river at this point was not strong enough to take the heavy loaded trucks and spray equipment.

We had to improve and rebuild one and one-third miles of road along the Michigan side of the river from the filling tank to the new spray area. This included cutting the grade for the heavily loaded tank trucks. In the spray area itself, we built approximately four miles of road in the form of a rectangle (see map). The Fluid Mechanics Division of the Kimberly-Clark Research Department designed a gasoline powered pump and spray unit capable of atomizing spent sulphite liquor to a fine spray and throwing it out to the side of the road a distance of 40 to 45 feet. This unit was mounted

*NOTE When well #7 was drilled, water was first encountered at 895 feet above sea level. In the ensuing weeks, the level gradually increased to 913 feet where it has held since that time.



PLAN SHOWING
SPENT LIQUOR SPRAY AREA
KIMBERLY & CLARK CORP. — NEENAH, WISC.

OWRC. SEPTEMBER 1958. J.H.

on a trailer and hauled behind the tank truck. The roads mentioned above were laid out in such a fashion that between the adjacent spray areas there was a strip 45 to 50 feet wide which would receive only the mist or vapor of the spray pump proper.

Operation of the System.

From late Spring until early Fall, we test the river daily for dissolved oxygen and bio-chemical oxygen demand. The sampling points just above the mill, one mile below the mill and five miles below the mill are standard. The sampling point five miles below the mill which we call station No.3 is the control point. Besides these, we sample at several points down river each day. The exact locations are dependent upon river conditions, namely temperature and flow. The sag in the dissolved oxygen curve varies both in degree and in location depending upon these two factors. We rarely sample farther than the dam at the Village of Kremlin which is 19 miles below the mill. Beyond this point, we have always found complete recovery.

We have arbitrarily set two parts per million as the minimum concentration of dissolved oxygen which we will maintain. (2) When dissolved oxygen tests at station No.3, supplemented by down river testing, indicate that oxygen concentrations are approaching this point, we begin diverting sulphite liquor to the storage tank and start hauling to the spray disposal area.

Each truck of 3,500 gallons capacity pulling a trailer upon which the gasoline powered pump and pressure unit is mounted, fills up at the liquor storage tank. Once it reaches the spray area, the trucks move at a predetermined rate of speed following a definite schedule. The pressure unit throws out a finely atomized spray for a distance of 40 to 45 feet on each side of the road. By regulating the speed of the trucks and the scheduled spraying routes, we hold maximum loadings to 1.00 pounds solids per square yard per 24 hours or less. Each round trip takes slightly less than an hour. Each truck therefore can haul 100,000 gallons in 24 hours. We are allowed by the Michigan state order to use up to 320,000 gallons of spent sulphite liquor on the disposal area each day.

We check for any effect upon underground water supplies by testing wells 1,5,6,8, and 10 (see map) and report results three times a year to the Michigan Committee on Water Resources. So far, no trace of spent sulphite liquor has occurred in any of the wells, in spite of the fact that between one and two million gallons were disposed of in this manner during the trial run of the system in 1956 and 15 million gallons during the summer season in 1957.

To find out what is happening to the sprayed liquor, we take soil samples from various depths up to 20 feet (see table) with an ordinary post hole auger. Samples are taken at four different points for each depth from the spray area, screened through an eight mesh sieve and composited. Each soil sample is then subjected to the following arbitrarily established test procedure.

(1) A two quart sample is placed in a container and ten quarts of distilled water at 76°F are added.

(2) The mixture is agitated for 15 minutes with a "lightning" mixture.

Table No. 1

Sample Depth Feet	k 20°C	Ultimate B.O.D. 20°C p.p.m.	5-day B.O.D. 20°C p.p.m.	Lag Period Days	Folin-Denis p.p.m.
		September 10, 1956			
Blank Area	.006	23.5	1.6	0	-
.5					
.5	.257	7.1	4.8	3.1	-
2	.118	21.9	12.2	2.0	-
4	.050	5.7	2.5	0	-
		October 10, 1956			
Blank Area	.207	9.3	7.4	1.7	19
.5	.035	102.7	26.7	1.3	149
2	.158	33.2	25.4	1.0	47
4	.098	45.4	9.3	4.0	19
		November 1, 1957			
Blank Area	.004	33.3	1.3	1.2	2
1	.175	9.3	5.1	3.0	144
5	.047	4.7	.6	3.8	4
10	.125	13.4	9.3	.7	36
15(1)	.063	5.2	1.3	1.6	24
20	.095	4.5	1.9	2.5	22
		November 26, 1957			
Blank Area	.224	1.7	1.6	0	12
1	.136	8.7	5.5	1.8	39
5	.060	24.6	8.8	1.8	76
10	.122	3.5	2.1	1.8	36
15	.096	2.7	1.4	1.8	39
20	.069	2.8	1.1	1.8	33

(1) Two distinct rates were obtained: .222 through four days and .063 thereafter.

(3) The water is drained off and filtered.

(4) Water samples then go to the Sulphite Pulp Manufacturers Research League Laboratory to be analyzed for ultimate bio-chemical oxygen demand, five day bio-chemical oxygen demand, the Folin-Denis value and finally the oxidation rate.

When considering the oxidation rate of an easily oxidizable substance such as the wood sugars in spent sulphite liquor, a decrease in the rate after a time should indicate decomposition of the more easily oxidizable substances. The same is true after percolation through the soil. The values given under the heading "k" 20°C are for a constant calculated from the following relationship: $L_t = L \times (1\text{-}10^{-kt})$. Where L is the demand at the time t and k the rate constant. This k represents the rate at which the biological oxidation progresses in the BOD bottle. In the soil, however, this rate is not necessarily constant because of environmental conditions not present in the bottle. Variations in this rate constant at various depths should indicate to a degree changes that have taken place in the sulphite solids. While the data thus far obtained are rather wild, this is easily understandable considering the uncontrolled conditions governing this experiment. The figures do generally indicate a progressive oxidation at the deeper depths. The accepted oxidation rate for Niagara spent sulphite liquor approximates .225. It is of particular interest to note that at no depth was a rate found approaching this figure. This would indicate that sugars are being decomposed.

In the table two sets of figures are given for BOD. One is the ultimate BOD and the other the five day BOD. The ultimate BOD represents the total demand for oxygen required to completely biologically oxidize the liquor under the particular conditions present in the sample. The five day BOD is the actual demand exerted over a five day period. It may, however, not be a true five day BOD since in most cases shown in the table, there is a lag up to as much as four days. The why of this lag period is not known. It is, however, the time in days required for the biological oxidation to start at the rate indicated by the "k" data. There is a general decline in ultimate BOD as the waste percolates to the lower depths. This is consistent with the declining rates as previously mentioned.

The Folin-Denis determination is a colorimetric procedure which while not specific for lignosulfonates, under the conditions used in this test can probably be considered a measure of the lignosulfonates present. When spent sulphite liquor percolates through the soil, some portion of the lignin will be absorbed by the soil particles and held firmly. This will continue to a point of saturation. The figures given in the table represent lignosulfonates that could be leached from each particular sample. They can be interpreted to indicate that liquor sprayed on the surface has penetrated to a depth greater than the 20 foot depths sampled. Further examination of the data would indicate that the wastes have been well stabilized when they reached the 15 foot depth.

The methods of sampling are admittedly rather crude even with the compositing of the samples. In a 40 acre area, variations will inevitably be great. The samples submitted for analysis have seldom been clear, even after filtering and once even after centrifuging. Absorbtion of lignin by the soil to the saturation point was experienced in the experimental column study of Wisniewski, Lueck and Wiley. Obviously, in a large area such as we use, there is no way of controlling degree of saturation or saturation rate, or of even determining these factors.

We plan to take samples twice a year. The area is sampled in the Spring before the hauling season starts and again in the fall at the close of the season. It is expected to have a rather comprehensive body of information after several years of operation.

Summary

The spray disposal system has proved successful in its first full season of operation. It has beyond all argument successfully accomplished its purpose, namely to reduce the pollutional load on the Menominee River. The year 1957 brought abnormally low river flows and high water temperatures. Under these adverse circumstances, critical conditions would unquestionably have developed in the river had the spray system or some equivalently effective treatment technique not been in operation.

To make use of this disposal method, a mill must have an area available which fulfills the following five conditions:

(1) There must be a sufficient depth of the proper type of soil above the water table to allow time for suitable bacterial action.

(2) The area must be large enough to allow spreading of the spent sulphite liquor at a concentration not exceeding one pound per square per 24 hours.

(3) The area must be within accessible distance of the mill.

(4) Enough must be known about the direction of flow of the underground water to assure that no wells will be polluted.

(5) The area must be far enough removed from habitation to minimize the undesirable aesthetic effects such as odor, unsightliness and wind carry of the spray.

As pointed out earlier in this paper, the spray disposal was chosen despite inherent financial drawbacks:

(1) Substantial Capital Outlay Required for the Installations: The cost to our Niagara Mill of installing spray disposal exceeded $110,000. This does not include the cost of the trucks which we lease with the operators from a trucking concern.

(2) Continuing Operating Expense: Truck rental alone totals $500. a day when we are using three trucks 24 hours. Road maintenance, mechanical repairs and storage tank maintenance run into substantial sums.

(3) Lack of any Compensating Income: Since the spent sulphite liquor is sprayed directly into the soil, no by-product of any kind is obtained from it.

Without making any charge to the system for depreciation, insurance or interest on investment, the mere operating cost during the three months basic spraying season rolled up the impressive added expense of $1.39 per ton on the total production of sulphite pulp produced for the entire calendar year. In short, during the three month spraying season, we added $5.56 per ton to the cost of sulphite pulp manufactured in the mill.

Because of these measurable disadvantages and despite its unquestionable effectiveness, we consider spray disposal only a temporary solution. We shall continue it only until research yields a better method that will answer the problem of spent sulphite liquor and stream improvement.

References

(1) Ponding and Soil Filtration for Disposal of Spent Sulphite Liquor in Wisconsin; Wisniewski, T.F., Wiley, A.J. and Lueck, B.F., TAPPI Vol. 39, No.2, Pages 65-71 (February, 1956).

(2) Van Horn, W.M. and Balch, R.F. "Reaction of Wall Eyed Pike Eggs to Reduced Oxygen Concentrations". Proceedings of 11th Industrial Waste Conference, Purdue, 1956, Page 319.

Van Horn, W.M. and Balch, R.F., "Minimal Oxygen Requirements for Certain Species of Fish". National Council for Stream Improvement Technical Bulletin 66, May, 1954.

Wildung, J.L., Ecology, Vol.20, Pages 253-263, 1939.

"Statement to Washington Pollution Control Commission Regarding Water Quality Standards Recommended by Director of Fisheries", by Northwest Pulp & Paper Association, Page 15.

Cooper, G.P. and Washburn, G.N., American Fisheries Society, Vol. 76, Pages 319-329 (1942)

FACTORS INVOLVED IN APPLYING AUTOMATIC CONTROL TO AN INFILCO CYCLATOR

- by -

Dr. H. M. McFarlane

Abitibi Power & Paper Co. Ltd.
Sault Ste. Marie, Ont.

J. R. Gunning
A. E. L. Maughan

Provincial Paper Ltd.
Georgetown, Ont.

In the public mind, effluents from pulp and paper manufacturing operations are usually thought of as involving vast amounts of water carrying either foul-smelling components or large quantities of suspended matter; Since the operation described in this paper is relatively small, it was thought advisable to point up the differences between it and those more common to our industry.

Newsprint production in this country requires 35,000 to 45,000 gallons of water for every ton of finished paper and the water usage in the production of other grades of paper is of the same order of magnitude. When it is considered that an average newsprint mill produces 400 tons of paper per day, some idea is gained of the volume of waste water to be sewered. In this country, with mills generally situated close to more than adequate supplies of water and far from large centres of population waste treatment has in the past become necessary only in isolated cases. However, with increasing population and a growing awareness on the part of the public of the dangers of pollution, management is becoming more and more conscious of the need for study of waste treatment or better still, waste utilization.

In brief, wood pulp is produced by three general processes, mechanical, semi-chemical and chemical. In addition to these, extensive use is made of pulp produced from waste papers. Each type of pulp offers a distinct problem in waste correction.

Mechanical pulp or groundwood, as the name implies, is made by grinding the wood into small fibres with an abrasive stone. The only waste is the water soluble material in the wood and the very finest fibres. Economic considerations make necessary extensive systems of white water re-circulation in order to recover all possible fibre and reduce fresh water demands.

By far the greater part of chemical pulping is carried out by two basically different processes, the acid or sulphite process and the alkaline or kraft process. Through the years the producers of kraft pulp have worked out methods of chemical recovery involving evaporation and burning of the spent cooking liquors. In this way pollution problems have been minimized. On the other hand, producers of sulphite pulp have spent countless thousands of dollars on study of the spent liquor problem without arriving at any satisfactory solution. In the normal sulphite process up to 50% of the wood used is dissolved in the cooking liquors. While in high yield processes this proportion has been reduced to around 35% no satisfactory method of disposal has been found for even this amount. Although relatively small markets have been found for lignin by-products, the limited nature of these markets has prevented widespread chemical converstion of spent liquors. Similarly in certain localities, spent liquor is used as a road binder and dust control on gravel roads. Again this use is limited by availability of suitable trucks and the economics of hauling as compared to competitive materials. It can thus be concluded that efforts to deal with the spent sulphite liquor problem have met with limited success.

Pulping of waste paper, rags etc. is carried out by caustic treatment of this material followed by washing and screening. Wastes carried out in the wash water consist almost entirely of suspended matter made up of rejected fibre and inorganic material removed from the raw material. Mills treating this waste have had considerable success in suspended solids removal using sedimentary type clarifiers. In this way up to 75% of the suspended solids is removed. A mill sewering 5,000,000 gallons per day would require a clarifier 120 feet in diameter with a 10 foot sidewall depth. This would give the recommended detention time of 3 to 4 hours. In addition, 3 acres of land would be required for sludge drying beds.

The papermaking process in common with all the pulping processes has the problem of suspended solids removal. In the pulping stage this problem has been minimized by a high degree of white water recirculation. Where this is not possible in the papermaking stage, savealls are generally employed. This equipment commonly takes one of two forms, flotation savealls or vacuum filters. The former type depends on the sudden release of air from a supersaturated solution of air in the white water. The white water having been treated with a flocculating agent, the air floats the floc to the surface where it is skimmed off and the material re-used. Vacuum filter savealls as the name implies depend upon filtration of the white water for removal of suspended solids. The white water is commonly sweetened with virgin fibre in order to increase the efficiency of the filtration. The clarified water from both types of saveall finds use as shower water etc. throughout the mill.

Concerning the "Objectives for Water Quality Control in Ontario" adopted by the Pollution Control Board in 1953, the pulp and paper industry could be affected by three of the objectives; those involving pH of the receiving waters, turbidity of wastes and deoxygenating wastes.

Both the pH and oxygen consuming properties of spent cooking liquor could conceivably violate these objectives. However; as has been mentioned previously most of the mills in this country, being situated near large water supplies, obtain more than adequate dilution of the effluent. Suspended solids removal accomplished by white water recirculation, savealls or sedimentation can meet requirements of turbidity control.

The general picture then, of the pulp and paper industry, is one of large scale water usage and disposal. Spent liquor studies have as yet not been successful but in most cases, ample dilution of the effluent has prevented any harmful effect on receiving waters. Suspended solids of a fibrous or inorganic nature are successfully removed by equipment now in use. This equipment handles large volumes of water and requires considerable control. This picture may be contrasted with that of the situation of the coating mill in Georgetown.

This division should more correctly be called a converting plant rather than a paper mill. No paper is actually manufactured although a good deal of it is processed. To summarize the operation one might say that paper is brought in, in rolls from our other Divisions and coated with a mixture of kaolin and adhesive. The web is then passed between the rolls of the supercalendar which smooth it before it goes to sheet cutting and trimming to be sent to the printing shops. Since there are no paper machines, the large volumes of water which we have referred to do not exist. True, the coating is made up in aqueous medium to be applied to the paper, but it is very similar to a painting operation and all the liquid that is present goes on the sheet and is dried in the drier tunnels. It is obvious then that there is no process water in coating of paper such as we have described in the manufacture of paper.

Handling as we do, great quantities of clay and adhesives, there is a good deal of washing up to be done. It is the water from these cleaning operations which has given us the problem of cleaning up the effluent from the mill. Besides washing out containers, mills, tanks and other equipment, a good deal of floor washing takes place. There is also a slight surplus of the coating mixture itself which has to be gotten rid of.

There has always been some provision to take care of the effluent water from the Georgetown operation but when the mill was small and operating on only one shift, it did not present a very great problem. At one time it was handled in a manner very similar to ordinary domestic sewage in that we had small tanks which would correspond to septic tanks, with weeping tile drains out under the land adjoining the mill. These weeping beds filled up and became useless and so the water was allowed to overflow from the small settling tanks to the neighbouring stream. In 1951 it became clear that the volumes passing through our small settling tanks were too large for adequate settling and so steps were taken to study the situation and install something more adequate. A weir was constructed to measure the flow but this did not prove satisfactory since the water came through in surges and it would mean that somebody would have to stay by the weir 24 hours a day. We, therefore, borrowed a water meter from the town and put it on the line running from our settling tanks to the stream. With this instrument we established that we were putting between 14 and 15 thousand gallons of water to the river daily. On checking our present flows we find that we are still maintaining this average quantity. It is interesting to point out here that this comes to 380 gallons per ton of coated paper made at Georgetown which is 1% of the volume we mentioned for a normal paper mill. This introduced a real problem when we started to look for equipment since there were a few who were conversant with such small scale installations. There were a few pilot plants of very small capacity but none in the range in which we were interested.

This statement should be modified in that when we spoke to the Infilco Co. of Tucson, Arizona they were quite co-operative and undertook to design a small clarifier for the volumes that we are handling. We understood that their experience was being gained by working with the U.S. navy on small portable installations for various camps and shore bases. Several flotation methods were investigated including one made by this company but we were unsuccessful in our attempts to make them function. After a good deal of jar testing and some very crude pilot plant work, we decided on the design of our installation. We decided we needed a surge tank to take care of the very irregular flow and thought we were fortunate in locating a steel tank at our Port Arthur Division. As things have turned out, we could do with a much larger tank but since it is installed, we have made do with it. We proposed pumping the water from this tank with a rubber vane pump to the Infilco Cyclator Clarifier. Our conception of the problem at that time was, with a flow meter and a level recorder on the surge tank, we could adjust the flow between the surge tank and the cylator so as to maintain a steady rate. We will enlarge on this aspect later but suffice to say here that this did not work out at all. From the Cyclator Clarifier the clear water was to flow from the top peripheral through to the line to the stream, while the mud was to be discharged out of the conical bottom by gravity on a time cycle. We were somewhat hesitant about this design for the mud discharge but were assured by the manufacturers that it would be satisfactory. A wooden box was installed to collect this discharged mud from whence it would be pumped daily to a tank mounted on our mill truck and hauled away to the mill dump.

There may be some here who are not familiar with the internal design of a clarifier of this nature so we will give you a very brief summary of its operation. The central draft tube is divided into two cylindrical compartments. There is an impeller which causes the water to rise up in the central section after it enters in the centre and as it rises it draws with it some of the mud which already has been precipitated. This aids in building up a good floc which flows over the lip of the inner tube into the outer section of the central draft column. The floc settles down in the outer column and continues down into the conical base of the clarifier. The clear water rises up into the angular space between the draft tube and the wall and overflows into the trough which is located around the outside edge. At the base of the cone, there is a valve which is operated periodically by a clock operated time switch and in the original conception the mud would drain out and into the box. Because of the characteristics of the settled material in the Georgetown plant, the mud did not discharge properly out of the cone. Two obvious faults were observed, one was that the material hung up and so a very slow sweep arm had to be installed to prevent the material adhering to the sides of the cone. The other fault was that the viscosity of the mud varied and if the material was thinned it would flow out at a much faster rate than if it was thick. It is readily seen then, that if the mud became thin it would all clear out of the cone very rapidly whereas if the mud became thick the discharge would be much slower and the mud would build up and become even thicker.

We have already stated that the surge tank we installed was not large enough for the service we are calling upon it to do. Our conception of continuous pumping from it to the clarifier was not practical and so the present system had to be substitued. We now run the pump at a rate fast enough to be equal to the most rapid input to the surge tank with a level controller to shut off the system when the level drops to a predetermined height. We also discovered that the volume of mud which we had to remove from the clarifier was in excess of the size that we had allowed in our mud box. The percent solids was lower than we had anticipated and so we installed a secondary settling tank. We also put in a positive displacement pump to move the mud from the first to the second settler and converted the so-called mud box to a waste colour box. We prepare most of our coating in the neighbourhood of 35 to 40% solids and since we cannot obtain this concentration in the mud from our clarifier it seemed foolish to dilute this material and reconcentrate it to a lower concentration. Accordingly, we had special lines put in from the colour making department for the operators to use when they had to discharge surplus or spoiled colour.

The pump between the surge tank and the clarifier has to be of the self-priming variety since we did not put a pit beside this tank. We also found that the rubber vane type pump would not stand up to the usage we were giving it, not for any reason of defective equipment, but rather that we were asking it to do more than the job for which it was designed. We settled on a progressive cavity type and protected it with a settling box and screen. To maintain the liquid level between limits, this pump runs for a wide range of different times or periods. The shortest period is about 20 minutes which moves approximately 500 gallons up to the clarifier. The longest time it has run continuously was in February of last year when it ran for 8 hours steadily and moved 8900 gallons up to the clarifier. For the first three months of this year the maximum seems to be 5 3/4 hours and 7500 gallons moved. These figures indicate the problem we have been up against from sporadic flow. When the master pump shuts off, the chemical feed pumps also shut down. The agitator in the surge tank runs at all times as does the agitator in the draft tube section of the clarifier and the wall scraper in the clarifier.

In the original work we did in the laboratory, we discovered that at least two chemicals were required to precipitate the solid matter in our waste water. We should point out that a good deal of our manufacturing process is devoted to making clay slurries which will not separate. We also buy a very high grade china clay from Great Britain and Georgia in the United States with extremely fine particle size so that we will get a perfect glazed surface on our paper. With so much effort being put into making suspensions that will not settle plus the fact that we use adhesives such as protein and starch which will act as protective colloids, it is little wonder that the problem of making this material clarify is very difficult. Besides the two inorganic chemicals we have found it necessary to use builders which are relatively expensive organic compounds. To eliminate the necessity of putting in mixing equipment, we conceived the idea of introducing our chemical solutions into the pipe line between the surge tank and the clarifier and utilizing the turbulence in this line. All the equipment that we have mentioned thus far is housed in a small wooden building outside the mill proper but the chemical feed pumps are housed in the basement of the mill. We therefore bring the pipe in question into the mill to the chemical feed pump location and then out again to the clarifier. This means that there are a number of elbows and fairly short runs which cause more turbulence and give us the time element we need and also the mixing action we need.

To emphasize the problem we will quote a few figures which illustrate the extremely high portions of chemicals we have to use. Aluminum sulfate is consumed at the rate of 750 parts per million of water which is equivalent to 3.2 lbs. per finished ton of coated paper. Calcium chloride is slightly less at 600 parts per million of the purchase chemical and based on the water. This works out at 2.5 lbs. per ton of coated paper. The expensive organic builders are used at 85 parts per million which is 0.4 lb. per finished ton.

Earlier we mentioned that the chemical feed pumps are located in the basement of the mill. There is a 50 gallon rubber lined tank feeding each one, which is supplied from a larger tank on the balcony in the colour making department. The connection is made with butrate pipe and the flow is controlled by float valves. Butrate was selected for its chemical resistance, and for the same reason one of the solution tanks is reinforced polyester. Plastic valves also had to be used and we found that the connection into the water line had to be of chemical resistant material. We will take this opportunity to discuss the chemistry of our process.

CHEMISTRY OF THE PROCESS

The two coagulating chemicals we use are alum or aluminium sulfate and calcium chloride. The reaction is usually referred to as "the double ion effect" and has been successfully used in coagulating milk wastes. The waste water with colour in it, contains ammonium hydroxide, making it basic. We estimate that the maximum waste water solids are 2% although very few tests have been made of solids; rather, the maximum feed rate of chemicals required for clarification has been determined by experience. Actually, trial and error chemistry as opposed to theoretical chemistry is our approach and seems to be the only practical approach to problems of our type.

We know that our coating clay will disperse only at a basic pH; at an acidic pH, it agglomerates. Hence, besides changing the pH or acidifying, the other functions desired of our chemicals are to remove or nullify the effect of our stabilizing chemicals such as casein or starch and to build the pinpoint floc first formed into one which will settle quickly. We are not certain of the chemistry; however, the following reactions are noted as our hypothesis about the actions:

(1) $6NH_4OH + Al_2(SO_4)_3 \xrightarrow{\text{pH lowered about 2 units}} 2Al(OH)_3 + 3(NH_4)_2SO_4$

30 second delay

(2) $(NH_4)_2SO_4 + CaCl_2 \xrightarrow{\qquad} CaSO_4 + 2NH_4Cl$

During the 30 second delay before calcium sulfate precipitates, the following may occur:

(3) Ca^{++} or clacium ion + casein ———— calcium caseinate

(4) Al^{+++} + casein ———— aluminium caseinate

There is also an action on starch which may be entirely due to pH change or may be more complex.

A buffering effect is inherent from the combination of the weak aluminium and ammonium ions with chloride and any excess sulfate ions. The initial surge tank pH of 6.5 to 8.5 is lowered to about 5 to 7 respectively. This buffering control permits us to add excess of the coagulating chemicals alum and calcium chloride.

The pin point floc is mixed next with gentle agitation with the builders. This causes further agglomeration of particles and increases the rate of settling very considerably.

Preliminary evaluations of these reactions were done by trial and error in the laboratory by means of "jar tests". They are excellent to compare clarity of supernatant, fragility of floc, and bulkiness of floc. However, they are limited for our variable flow type of problem when a surge tank is not available to sample accurately. Small pilot plant equipment would be the only way of accurately evaluating builder action, mud properties, instrumentation, and surge capacities, without building the full plant. Again, the surge tank for sampling would be essential.

INTERMITTENT OPERATION.

As explained, our system has to be run on a start-stop principle by the level controller. Since settling continues while the system is off, there is no sludge in the draft tube or central builder mixing zone each time the system starts. This is not harmful as there is no sludge blanket concept involved now. There is sufficient clay and gypsum at all times to promote settling by weighting the floc down, although there is less clay for weighting on weekends. However, on weekends, there is also less flow, permitting a longer settling time and giving virtually the same effluent turbidity.

The continued settling and compacting of the mud when the system is off increases the mud viscosity. Occasionally, depending on the length of time between cycles and the rate of mud compaction for the particular waste, the mud viscosity can increase to the consistency of thin peanut butter. While this thick mud which is about 20% solids is somewhat thixotropic, it has always been found to flow, even if very slowly, when manually discharged from the primary or secondary sedimentation units. From both units the pressure is about 7 psi. A very small flow of water with this thick mud lowers the viscosity markedly. By manually opening a valve in a water line tapped into the bottom of the clarifier, we can introduce this water and thus clear the blocked line. However, to prevent these blockages, the mud pump must be capable of moving the mud before this extremely thick condition occurs. Another effect which has caused mud line blockages is bridging so that thin water flows out the bottom even though considerable mud is in the inverted cone under the primary sedimentation unit. Likely; a bridge or arch forms but also gases are formed from fermentation, bringing the mud to the density of water. The mud scraper has eliminated this problem.

Needless to say, the addition of the secondary mud settling or sedimentation tank has alleviated this problem since more mud can be pumped, making thinner mud. The upward flow rate through the secondary sedimentation tank is always lower than in the primary so that the effluent will always be as clear or clearer. Also, the mud concentrating continues in the secondary unit and this unit has been found to have ample capacity for a day's mud, preventing mud laden effluent water.

CONTROLS, INSTRUMENTS, AND ALARMS.

Controls

If our waste water system ran continuously, the controls discussed here would not be very critical, but with our start-stop operation, they are essential. The two basic controls of the waste water system are a bubble tube for water level in the surge tank, and an interval timer for mud discharge. The bubble tube is supplied with a very small, constant flow of compressed air from the mill compressed air system. A back pressure is created which is a direct indication of surge tank level. When the level and back pressure rise sufficiently, an accurate pressure switch turns on the progressing cavity pump, and the interval timer. Then, when surge tank level and back pressure drop by the amount of the pressure switch differential, the switch disconnects, turning off the whole system. The waste water system is so wired that if the progressing cavity pump motor cuts out on overload heaters, the whole system will stop until the overload is manually reset. Also, if the mill air compressor fails, the bubble tube back pressure drops, causing the whole system to switch off.

The bubble tube was originally installed to actuate the level recorder but the pressure switch connected to it was found to be an excellent controller. Floats would likely have jammed in our waste. An electrical shorting device could not actuate a level recorder.

The other basic controller, the interval timer, which runs only when the bubble tube pressure switch is on, makes an eledtrical connection for an adjustable percentage of its 15 minute cycle. When this electrical connection is made by the timer, the internal gear, mud pump starts, and by means of a solenoid and compressed air, a valve opens in the mud line, between the sedimentation unit and the secondary settling tank. When the timer switches off on its 15 minute cycle, the pump stops and the valve closes to prevent flow which might increase the mud viscosity at some point in the pipe. If the bubble tube pressure switch goes off while the mud pump is on, the timer's wiring shuts the mud pump off along with the rest of the system.

This timer control of the mud pumping was chosen as giving the greatest control flexibility, that is, a variation of 1 to 100 times the flow. Rather than a small, continuous flow pump which might block, a large volume, positive displacement pump is considered essential to keep out mud moving. Only one speed gives proper characteristics for our type of pump so that speed changes were not suitable for variations.

The bubble tube pressure switch also starts the proportioning pump and a running time meter. Various proportioning pumps have been used during the course of development but one, two or three can be plugged in to run when the system is on. While one motor may drive from one to four pumping heads, all heads have an adjustment so that the flow of each chemical solution can be varied. The main requirement of the proportioning pump is reliability. The ratio of alum to calcium chloride is extremely important and should be kept within a 10% tolerance, otherwise a very hard material can form in the sedimentation unit which will block the mud lines. The running time meter is simply a clock with a counter, reading in tenths of hours. By measuring the chemical solution supply tank levels and reading the running time meter every 8 hours, calculation gives the flow rates for the chemicals. This can be compared with the desired standard for a particular flow rate of the progressing cavity pump.

Several other devices are necessary to keep the waste water system functioning properly. A flapper type check valve is located on the main waste water line just beyond the progressing cavity pump. Without the check valve, when the pump is worn, there will be backflow when it is off. This means that acidic water from the sedimentation unit flows back to the surge tank, decreasing the pH. With low surge tank solids, acidity causes coagulation or precipitation in the surge tank. While this coagulated waste, when next pumped up to the sedimentation tank, will give clear effluent, the floc will be bulky and will not settle nearly as quickly as usual. This effect is especially severe with one of our types of coating. Hence, precipitated floc can be carried over with the effluent water.

The effluent water outlet for the secondary sedimentation tank is a pipe which swivels to permit raising and lowering the open end. Except when removing mud, this pipe is in the top position. If the open end is lowered to just above the mud level, the clear water can be decanted and the mud level read from calibrations. If the clear water were never decanted, mud bridging would occur as it has in the main sedimentation unit without a mud scraper. However, with an air-mud interface, the mud will drop quite easily.

Two screens are used to prevent the progressing cavity pump from blocking. One is an open, slanted type screen above the surge tank. The other is in a metal box on the suction side of the progressing cavity pump. This box must function under partial vacuum and hence is built leak proof. Any air entrainment will float the mud and give dirty effluent. While there is a screen here, the majority of the residue is sand which settles as the flow rate decreases in this box. Knitted cotton "filter socks" are used ahead of two of the proportioning pumps to trap residues obtained with the commercial chemicals used. In addition to the screen protection, all pump motors are overload protected.

It should be pointed out that one of the fundamental controls, involves surge capacity. There are three types of surges which can plague our system.

1. Waste water volume surges. The volume above normal in the surge tank, along with the progressing cavity pumping rate selected, keep these surges within control.

2. Surges or changes in waste water concentration. The appreciable volume always maintained in the surge tank evens these concentration changes.

3. Mud volume surges in the primary sedimentation unit. The large mud storage section here and the higher mud pumping rate to the secondary sedimentation tank even these fluctuations.

Instruments

Certain instruments are used to indicate and to record characteristics of the system on the waste water panelboard in the Mills Test Station. A level recorder for the surge tank level is actuated by the bubble tube back pressure. This can give a great deal of information when interpretted by experienced personnel and is surprisingly accurate. There are three pressure gauges which show significant pressures at various points in the system.

There is also space on this panelboard for another recorder for a turbidimeter which we intend to try to invent. This would measure concentration of particles in the clear water about 3½ feet below the surface of the sedimentation unit. Such an instrument should record continuously even if the system is in control, so that variations can be studied and related to changing plant waste conditions.

Alarms

The bubble tube described under "Controls" sets up a back pressure related to surge tank water level. One pressure switch connected to this back pressure controls the whole system. However, another identical switch is connected to this back pressure but set to switch for a surge tank level just below flooding in case of pump failure or excessive flow to the surge tank. This switch rings a bell near the Test Station to warn mill personnel who are present at all hours of the day, 7 days per week. The level recorder in the mill is very helpful in diagnosing what has happened when trouble occurs and what action is required.

The proposed turbidmeter discussed under "Instruments" would require a recorder, which would likely include a servomotor. Such a recorder can be arranged very easily to throw a switch at a set high turbidity level. The switch could be connected to an alarm bell to warn plant personnel that something is wrong. Since there is over an hour time delay at present pumping rates from the time that a turbidimeter 3½ feet below the water would record high turbidity until this turbid water would leave the mill, corrective action could be taken during this time. Accordingly, a turbidimeter recorder and alarm along with our present high surge tank alarm would permit complete control of the waste water system, automatically. At present, the turbidity observations are made regularly by the troubleshooter but this is quite expensive in terms of skilled labour.

WASTE CONCENTRATES.

Note that two types of waste concentrates are produced, the dispersed waste "colour" and the precipitated mud. Colour is the term applied to the liquid material we coat onto paper. Since this colour is made up in batches which must stand before use, a little extra must always be made to use up all the paper raw stock for a particular run. About once or twice every twenty-four hours some of this colour must be disposed of along with a little water to rinse the drains. The mud is produced by coagulating dilute slurrys of this colour (wash water). Hence the only solids added to the colour are precipitating chemicals. The average properties of these two waste concentrates are:

Precipitated Mud

pH 5.5 - 7
solids 10 to 17%
odour - quite characteristic
filterability - possible but very slow
solids after filtering - 40%
approximate analysis of the oven dried part:-

inorganic coating clay	75%
precipitating chemicals	12%
Organic matter (casein, latex, starch)	13%

Waste Colour

pH 9 - 10
solids 30%
odour - only ammonia
filterability - nil
approximate analysis of the oven dried part:-

inorganic coating clay	85%
organic matter (casein, latex, starch)	15%

The total average oven dried solids per working day is 3/4 of a ton and this is contained in 1500 gallons on the average. These figures include the combination of precipitated mud and waste colour.

From one to two years' work has been expended examining methods of disposing of the waste concentrates in an economical manner. At the present writing, 18 different processes have been examined and all have been found to be quite expensive and difficult to control automatically to give an easily disposable waste, which is more concentrated than that obtained by sedimentation. For any one contemplating a waste disposal program, it is suggested that the disposal of the concentrates be considered almost the most difficult part of the problem. While we have considered the possibility of useful by-products, we have found none which might be of sufficient value to pay for the further processing required. Since our mud is odiferous, disposal of it by dumping into an open pond has lead to objections from nearby residents. Deodorants and disinfectants have proven unsuitable. Anaerobic digestion as done in sewage plant digestors has been tried in the laboratory but elimination of odour was not obtained. Also the common chemical engineering operations of filtration, centrifuging, and drying have been examined in terms of a number of commercially available pieces of equipment. All were very expensive in terms of the initial and/or operating expense. It seemed doubtful if any of the filtration or drying equipment could be left unattended for days or weeks at a time, as we hope our present sedimentation equipment can be. This lack of automation meant considerable labour which set the high operating expenses for our small waste volume. Ponding still seems to be the most satisfactory method of disposal of the waste concentrates, despite the distance now travelled to the dumping area to get away from centres of population.

OPERATING WORK AND SUPERVISION REQUIRED.

Our coating mill is on 3 shift, 24 hour per day operation. Various mill personnel are utilized in the operation of the waste system. The job names for these personnel are the truck driver (on day shift only), the special colour men (on two shifts per day), the plant testers (on three shifts), the millwrights maintaining mechanical equipment and the trouble shooters or supervisors. These men combined do the following operating and control jobs:-

1. Remove mud and waste colour on working days. This work takes about two-thirds of the total time required for operating the waste water system.

2. Check that mud is flowing freely to secondary sedimentation tank daily.

3. Clean various equipment around the waste water shack and the proportioning pumps. This work is very important to the maintenance of the waste water system. A screen above the surge tank is cleaned daily along with hosing down the floor. Three times per week a screen and settling pot ahead of the progressing cavity pump is cleaned. About weekly, filters in the alum and calcium chloride tanks ahead of the proportioning pumps are cleaned. When necessary, sludge from the bottom of the waste colour tank is hosed out. About every two months, the bubble tube needs cleaning as do the sides of the main sedimentation unit. The sedimentation unit is cleaned by means of a long handled hoe without draining it.

4. Solutions of the coagulating chemicals and builders are made up when necessary which is about twice a week.

5. In order to check the flows of the proportioning pumps, once every 8 hours liquid depth measurements are made on the chemical solution supply tanks along with a reading of the running time meter. This can then be calculated as flow rates about once a day or is available if trouble shooting.

6. Normal mechanical maintenance such as greasing and rebuilding of pumps is done as required.

7. Trouble shooting and supervision is now done by the Development Engineer. However, this will be turned over to mill personnel very shortly. The basic contact with the system and understanding of it comes from a weekly checkover of the entire system. This permits the person doing the checkover to know the settings currently being used and also any weaknesses of any parts of the system. Then, any difficulties can be better diagnosed.

8. If there are any difficulties in the system, a trouble shooter needs to be called, possibly only by telephone. Difficulties causing the high level alarm to ring have in the past frequently been diagnosed and cured by mill personnel. This type of procedure may be suitable in many cases in the future, although situations have occurred and will occur where the trouble shooter must come to the mill and diagnose the difficulties.

9. Since there is at present no turbidimeter and high turbidity alarm, the Development Engineer makes regular visual checks on the turbidity of the effluent water. This will not be necessary if a suitable turbidimeter is invented.

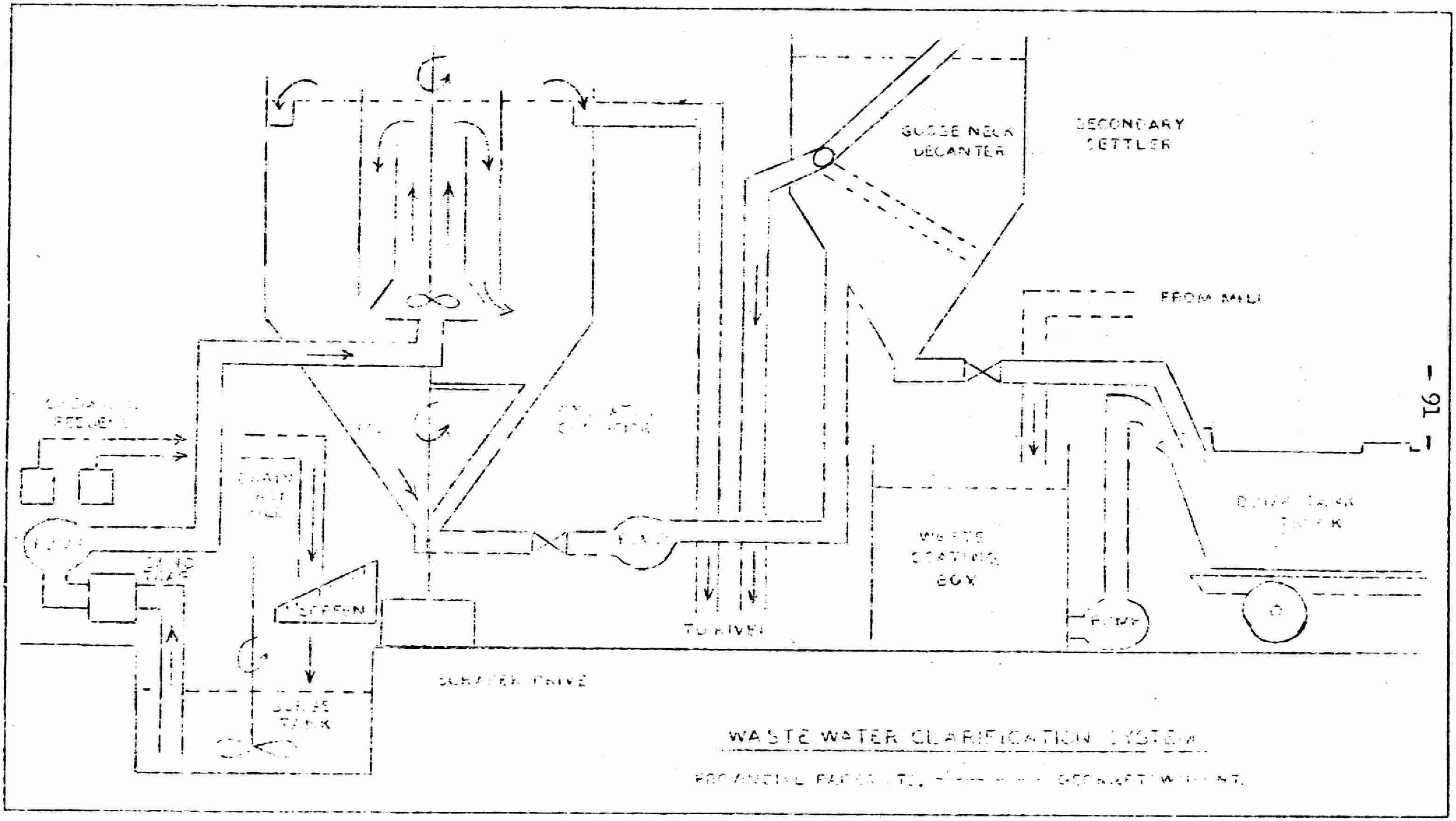
10. Since the trouble shooters are the only real "operators" of the system, one should be on hand to change settings or to operate the system manually when necessary for shut downs, design changes, or when major overhauls are undertaken. Such design changes, now that development is essentially finished, should not happen very frequently and overhauls should not be necessary much more than once per year. Even these overhauls may frequently be done on Sunday when no shut down problem will exist.

May we for a moment consider the situation the Georgetown Division of Provincial Paper found itself in when initially designing this waste water system and during the development stage of putting the system into operation. Insufficient space was available to use a ponding technique for dealing with this waste. Hence a relatively small, high throughput unit had to be selected. After the unit was set up and had been operated for a short period of time, we discovered we could not keep silica sol stable over a week-end. It was decided to use more expensive chemicals. The small flows of waste water involved and the relatively small size of the Georgetown Division could not justify one or more full time operators who had sufficient ability to manually operate the system. This has meant an appreciably greater cost in terms of technical development time and the use of excess chemicals, but has produced a unit which may soon be almost completely automated. This also means that preventative maintenance in all its aspects becomes extremely important to the economical operation of the unit.

A very important characteristic of an automatic system such as ours should be pointed out. Once the system is set properly the controls should be changed a minimum of times. After a major change, the whole system must be checked over and it can be run for two or three hours and then observed as a further check. However, small changes should be kept to a minimum since it is only human that one of the scattered controls may be forgotten when resetting. Automatic electrical equipment is much more reliable over a period of months than human memory.

During development stages this system has quite literally evolved. This should be considered normal for an automatic system, since the variables in a system such as ours are so complex that they cannot be completely designed for. This evolution will continue. We can count on some changes always occurring in our mill such as formulations, operating procedures and men with their pet habits. These changes sometimes change ratios to create changed problems, even if they are not completely new ones. Also improved pumps or chemicals may be found which will make the system evolve. Accordingly, a trouble shooter must always stay up to date to be effective.

When troubles occur in the system, diagnosis is frequently the key to preventing turbid water from leaving the system. With this automatic system, one maladjustment will usually throw two or three other factors out of adjustment. When trouble occurs the Development Engineer has found from experience that a complete check-over of the system is essential. This usually takes about one-half hour. He found himself fooled very frequently if the check-over of the entire system was not made before diagnosis.



WASTE WATER CLARIFICATION SYSTEM

PROVINCIAL PAPER LTD., [illegible] GEORGETOWN PLANT.

A REALISTIC APPROACH TO PLATING WASTE TREATMENT

- by -

Edmund B. Besselievre, Mem. Amer. Soc. C. E.*
Consulting Engineer
Manager, Industrial Wastes Division
K & H Engineering Company, Toledo, Ohio

The priceless ingredients in the solution of a plating waste treatment problem are:

1. Competent engineering and technical advice.
2. Realistic and logical requirements by regulatory agencies.
3. Reliable information and data on the wastes.
4. Practical design by the consultant.
5. High grade construction.
6. Dedicated operation.

In any given case all of these ingredients are important, but regardless of the excellence of the first five, unless the sixth is also present, the efficiency of the others will be nullified.

Let us scan each of these ingredients in their order.

1. Competent Engineering and Technical Advice

As there are many variables in any plating waste problem, the consultant or specialist called upon to design a practical and economical plant for his client must be an unbiased person with no special leanings toward any given method of treatment or disposal of the wastes, or to any special type or make of equipment, apparatus or control devices.

There are many varieties of excellent equipment on the market which have application to the treatment of wastes in certain cases, but I have always maintained that there is no one type or make of equipment that is suitable for every case. The manufacturers themselves agree with this. Therefore, the consultant should be open-minded as to the equipment and apparatus for a given problem, to select and use that which is best for that case only. He should be able of his own volition to evaluate the conditions in a given case and arrive at the most practical and economical conclusion without pressure from a given manufacturer. Having decided on the equipment that in his opinion is best for a certain problem, he should then consult with the manufacturers of that equipment to be sure of getting the latest models and their advice as to his proposed use. A manufacturer knows best the limitations and applications of his product and he is entitled to the privilege of working with the consultant for its best use.

As there are usually several methods of treatment of a given waste, the consultant must have sufficient background knowledge of all of them to enable him to properly evaluate the actual conditions in each case, and to apply that method which will produce the desired result in the most practical and economical manner.

He must always keep in mind that in the majority of cases the treatment and isposal of industrial wastes is an expense for the plant for which it is designed. In the average case the plant owner cannot expect to recover any substance which will return a profit on the operation of treatment, or even produce any revenue whatever. Therefore, it is the consultant's duty to scrutinize every condition carefully, with the local situation in mind, to work out the plant that will produce the results at the lowest cost per day. Too many industrial owners look at the first cost and do not consider the daily cost. The first cost of a plant is an item of capital investment and becomes an asset of the company, but the daily operating cost of the plant becomes an item of overhead which must be absorbed into the cost of production of the item manufactured. In these times of close competition no manufacturer wants to add anything to his cost of production. Therefore, frequently a few dollars spent in initial plant cost may save enough to write off the extra investment in a very short period.

Let us take an example. Assume that for a certain treatment it works out that the initial plant will cost $50,000.00. With fixed charges at 5 per cent for amortization and 5 per cent interest on the investment, with labour, chemicals, electric current, etc. the plant costs $48.50 per day to operate. That is $14,550.00 per year on a 300-day basis. Now, suppose by proper study we spend $70,000.00 for the initial plant but we reduce the cost of the plant operation by $10.00 per day. The total annual cost of operation then becomes $11,555.00, the saving is $3,000.00 per year, and this will pay off the additional $20,000.00 of initial investment in less than seven years.

The consultant should survey local sources of materials and the availability of wastes from other nearby plants which may be obtained at low cost or no cost to react with the wastes in the plant to produce results at little or no expense for reagents. This may well solve two problems at the same time, or it may require a pipe line or a tank truck to haul the one waste to the other plant, or a treatment facility located between the two. The extra cost of the pipe line or the truck will soon be absorbed by the saving in chemical and operating costs. For instance, a plant having an acid waste pickle liquor which would require expensive neutralization may be adjacent to a plant having a highly alkalins waste which would require the addition of an acid neutralizer. Bringing the two together would solve the problem for each. There are numerous other waste products which may be thus used to advantage with marked reduction in operating cost. Any manufacturer who has a waste which he can dispose of to another manufacturer and at the same time solve his problem, will usually be willing to give it at no cost, or perhaps for the cost of transportation only.

Thus, the consultant should be conversant with all methods, with the advantages to be gained for his client by the careful study of other local sources of reagents, etc. The presence of a certain material in the near vicinity of the plant, however, should not blind him to a careful study of the economics of using this material as against another which may come from a distance but which is cheaper to use. He should be able to evaluate the costs of different proprietary coagulants or precipitants against the cost of common, readily available chemicals that may do the same work at less overall cost.

The consultant should recognize that his duty is to his client, to survey all angles of the situation and to work out independently of all others, a practical and economical solution. If the consulting firm called upon to solve a waste problem for a client is not a specialist in this work, it should engage someone who is expert in this phase to work with them on this project. There are many sad examples of expensive waste treatment in existence, or that have been cast aside, because the designer did not know all about that particular waste.

The consultant should not, nor should he be asked to, give an estimate on the cost of a waste treatment plant until he has studied all the facets of a problem and arrived at what he feels is the most practical and economical solution for that particular case. Just because he had a problem with a similar type of waste the day before should not lead him to the false conclusion that the one of today should be handled in the same manner.

These points are particularly true for plants of the subject of this paper. Plating wastes are highly toxic and complex and treatment is expensive.

2. Realistic and Logical Requirements by Governmental Agencies

This is a very important phase for the consultant. Practically every State in the United States and many provinces in Canada have established limitations on the concentrations of toxic or polluting elements in wastes which must be the basis of treatment. These requirements are somewhat general in their aspect as naturally no governmental agency charged with the elimination of, or prevention of, pollution in their streams can set up a general set of regulations and requirements that would meet every case.

However, where there are requirements of record, it is the duty of the consultant engaged for a given problem to consult with the proper regulatory officials, state or province, county, municipal, etc. to enable him to work out a satisfactory solution for his client.

As plating wastes contain highly toxic elements, such as cyanide, hexavalent chromium, lead, zinc, nickel, copper, etc. the concentrations of these which are permitted in plant effluents vary widely but are usually quite stringent.

For instance in some of the United States the requirement of residual cyanide in effluents varies from 5.0 p.p.m. to one case of "substantially none". In many cases the maximum is 1.0 p.p.m., or in several 0.1 p.p.m. To reduce cyanide in a waste to 0.1 p.p.m. when 1.0 p.p.m. may be sufficient is to work a severe hardship on the waste plant owner.

Frequently when a State has set up a standard for a given stream, say 1.0 p.p.m. but the treated wastes from a plant are discharged into a city sewer system, the City will pass along to the industry the State requirements. This, I maintain, is inequitable, as it gives no credit to the waste producer for the dilution available in the sewers. Thus, if there were a dilution of 10 to 1, and the industry is required to treat to 1.0 p.p.m., the effect of this dilution is that when his waste reaches the city sewage plant the cyanide is 0.1 p.p.m. Why then make him go to the added expense of reducing his wastes to 1.0 p.p.m. when on this basis he could discharge a waste with say, 5.0 p.p.m. and still have a final result that would satisfy the State, when the combined effluent reached the stream.

To illustrate the need for careful scrutiny of the requirements of cities and states we now have projects in one state where one city requires a final cyanide concentration for wastes entering into its sewers, of 1.0 p.p.m., a second city requires 5.0 p.p.m., and a third requires only 10.0 p.p.m. The difference in cost to a manufacturer to treat a similar waste thus would be 5 to 10 times what it would be in another.

If the waste is to be discharged directly into a stream then the state requirements should govern, bur here again these should be tempered with the necessities of the given stream into which they are discharged. To this end the classification of streams, already in use by a number of states, is the most equitable plan. It is certainly not equitable to compel a manufacturer to produce a waste suitable for discharge into a stream used for potable purposes if the waters of the stream to be used are not used for potable purposes.

The sooner regulatory authorities realize that if they adopt conservative and realistic requirements and are willing to sit down with a manufacturer and his consultant and discuss each problem on its merits, the sooner will all industries be willing to get under way with their waste treatment and abatement plans.

Therefore, the consultant should investigate not only the requirements of the state in which the wastes will be discharged, but also those of the city in which the plant is situated, if the treated wastes are to be discharged into a city sewerage system.

In a number of cases, where rivers rise in one state and flow through another, there may be conflicting requirements, which must be ironed out according to the needs of the river at various points.

In my long experience I have always found that regulatory officials are willing to cooperate with industry by having a round table discussion with the owner, the consultant and a representative of the agency involved. In this way a reasonable target can be established. The owner then will know what he is up against, the consultant will know how to meet the demand, and the plant will be built.

3. Reliable Information and Data on the Wastes

It goes without saying that this factor is of major importance in designing a practical plant. No waste treatment plant, especially for such complex and toxic wastes as those from plating operations, should be based on word of mouth information or judged by what was done at another plant.

The consultant should always consider it a basic part of his engagement to ascertain for himself the volumes of wastes to be treated, the concentration of toxic or polluting agents, the plant operating schedule, the variety of the wastes, any proposed plant additions which will increase the volume or strength of wastes, and any proposed change in processes which will change the characteristics.

In my experience we have recently completed a large project which we were called upon to design and build on the basis of a survey of waste flows and concentrations made by another highly competent engineering firm. However, when the plant was put into operation, immediately in two of the six waste flows, the volumes were an average of 30 per cent above the maximum designed capacity and the concentrations of toxic materials were 400 per cent above the original figures. Fortunately, in this case, provision had been made in the design for additional plating lines and an overload factor above all, and despite the fact that the flows were greater and stronger than had been planned for the equipment in the plant had sufficient capacity to handle the overload.

The consultant should satisfy himself, if necessary, by taking his own samples and making his own analyses, as to the amount and concentration of wastes that he must prepare to handle. In many cases, the engineering staff of the plant may be used to obtain this data at less cost than by the consultant. As a matter of fact, the plant staff of a large manufacturing operation is better qualified to get this data than the outside consultant, as they know the plant practices, periods of operation, etc.

Not only must the consultant know the total volumes of flow and the concentration of elements, but he must know the period of time in which the wastes requiring treatment are to be discharged to the treatment plant, what constitute continuous flow during the operating period of the plant, and what are dumps, contributing a heavy volume of wastes of strong concentration in a short period.

In a recent case handled by our firm, there was a steady flow of cyanide and metallic wastes rinses during the day. At intervals there were dumps that were low in volume but extremely high in concentration. In this particular case of the cyanide wastes, the daily volume of rinses was 207,000 gallons with a cyanide load of 409 pounds per day. At periods of once per week, once every two weeks and once per month, there were dumps of tanks that contained very high amounts of cyanide. If it happened that all of these dumps were to occur on the same day and were to be treated that same day, the total amount of cyanide was estimated to be 5205 pounds. To treat that amount of cyanide in one day, to nitrogen and carbon dioxide, would theoretically require 33,550 pounds of chlorine. To dispense this in 16 hours would require an installation of nine 6000 pound per 24-hour chlorinators and accessory equipment. Assuming that these dumps occurred on the same day, most of the expensive equipment would sit idle for the balance of the month. This evidently was an impractical and uneconomical solution. What was the remedy? First, a scheduling of the dumps to assure that they were not all dumped the same day. This required attention in the plating plant. The client refused this. The alternative then, which was adopted, was to provide separate holding tanks for the dumps and to provide pumps from these tanks of such low capacity to pump the strong wastes into the weak, that the average concentration was such that the total theoretical demand for chlorine per day was 5384 pounds, thus only requiring three 6000 lb. chlorinators. By this restriction of pumping capacity the operators of the plant could not upset the program by emptying the strong wastes into the weak in a short period. To provide for this the strong cyanide waste tanks were made large enough to hold all of the dumps in the event they were made on the same day.

In this case it was essential that the consultants should know about these dumps and their concentration in order to properly plan the treatment works.

Many manufacturers are reluctant to have outside engineers working in their plants where special processes or secret work is in progress. However, the consultant should make it clear to the plant owner that he is not interested in knowing any of the manufacturer's secrets or trade processes and that any information along that line that comes to his men would be considered entirely confidential.

4. Practical Design by the Consultant

This phase reacts directly on the client's pocketbook.

There are two ways of solving a problem and designing a plant. One is to follow blindly a description of a seemingly similar type of problem, the other is to consider all the elements of a situation, take into account all the local factors and design around those factors. The latter is the one that will more assuredly satisfy the needs and suit the client's exchequer.

This practical design takes in many factors, among which may be mentioned:

1. The local situation as regards the point of discharge of the wastes, directly into streams or into sewerage systems.
2. The effect of the constituents of the wastes on the particular type of sewage treatment plant the city may have, which will indicate the scope and degree of treatment necessary. Plating wastes usually contain considerable copper. Copper willuinterfere with bacterial action in digestion tanks. If the wastes contain iron and an activated sludge plant is used, it will clog the diffuser plates.

3. The combination of wastes to achieve mutual reactions, whether from wastes existing in the plant or those that may be obtained from another plant.

4. The area available for the plant, which may dictate tank diameters and depths and placement of units.

5. The degree of revision of plant operations which may be permitted to reduce volume and/or strength of wastes.

6. Whether to use steel tanks or concrete tanks.

7. Accessibility for chemical supplies and materials needed in the treatment.

8. Location of units to permit ready access for reception and disposal of products and sludges, etc.

9. Use of fadtory means for air, steam, water, etc. to eliminate duplication in the waste system.

10. Availability of chemicals which may warrant a switch in methods used.

11. Extent of automatic controls desirable or as wanted by the client.

12. State, city or other regulatory agency requirements as to final effluents, and the point at which these will be determined.

13. Survey the possible reuse of the treated effluent and the additional possible treatment needed to render it suitable, and many others, including such local phases as the standing of the industry in the town, the taxes it pays, what it may expect from the city in cooperation that will reduce cost, political expediency, position of the company as regards its public relations program with that particular city.

Like doing the impossible, the second method requires more attention on the part of the consultation but the result for the client will be better and the client should be willing to pay for the additional cost of doing the job properly.

5. High Grade Construction

It goes without saying that construction should be of the best, and many times a reliable and experienced contractor can introduce savings and improvements which may hot have occurred to the designer. Where toxic materials are concerned, the care in building tanks and foundations to avoid leakage is important. Careful lining of tanks to prevent pin holes which will ultimately cause the total destruction of the vessel. Proper regard to safety factors established by local codes of which the designer does not know. Railroad requirements for side tracks. Utility obstructions and how to circumvent them.

In a recent case the area allotted for the waste treatment facilities was partly occupied by a high tension electric power tower. Two large tanks were to be built close to it. Exploration showed that each leg of the tower went into the ground about six feet and on the bottom of each leg was a steel plate about six feet square. To excavate in the close vicinity was dangerous. The solution was to substitute for the concrete tanks formerly shown in the ground, steel tanks on concrete foundations entirely above ground. This was not a condition which appeared in the first stages of the design, but came about when the power company looked over the plans.

High grade construction may seem expensive but in the long run it pays off, as it eliminates repairs and maintenance. A leak in the bottom of a tank holding toxic materials may require dismantling the tank completely, at heavy cost, whereas more care in the beginning would have saved this expense. This is one reason why the selection of the lowest bid is not always the wisest course. The selection of a contractor should be made in the following bases:

1. Record of satisfactory work for others.
2. Familiarity with the work to be done.
3. Competent field superintendents.
4. Ample financial ability to overcome delays in work which may hold up payments.
5. Amenability to discuss points of argument and make adjustments.
6. An inclusive bid which will avoid later charges for extras unless changes are made by the owners or designers.
7. Familiarity with the locality of the job to be able to schedule his work in line with the weather possibilities.
8. Means to get his materials on the job at the right times.

6. Dedicated Operation

Of the six priceless ingredients, this one, in my opinion, is the most important. A well-designed, poorly constructed plant may be made to function by a skilled operator. A poorly designed, well-constructed plant may likewise be made to function by the proper operator. And even a poorly designed, poorly constructed plant may frequently be made to function by a skilled operator. But even the most expertly designed and carefully built plant can be an utter failure if the operators are not interested and competent.

A waste treatment plant, particularly one for the treatment of toxic wastes such as those from a plating plant, is a complex mechanism. It contains many different types of equipment, control instruments, intricate apparatus, of all types. These must be kept in top notch condition to give reliable function and records.

The operator of a waste treatment plant should not be someone picked at random from the existing staff and handed the job of operating this complex unit. He should be a man carefully selected because he has had the basic training in engineering, chemical engineering, mechanical ability, etc., to be able to understand the principles on which the plant is designed, to be able to root out the reason for troubles that may occur in operation and to remedy them or to know where to turn to others.

He should be familiar with every detail of the plant he is to control. I have always recommended that when a waste treatment plant design is begun that the client make the appointment of the Chief Operator and have him available for conference with the designer and present at all times during the construction. It is easy to study the plans of a plant but it much better if the Chief Operator is on the ground during the construction for then he sees all the details of the work, he knows what the various mechanical elements look like, where the valves and pipe lines are and what valve controls what.

Practically all of the United States and many of the provinces of Canada now require operators of sewage and water treatment plants to be licensed and to have passed examinations as to their fitness. Industrial wastes are much more polluting than sewage and it would seem logical to require that operators of these complex entities should also be required to meet the same requirements. This would save a lot of headaches on the part of the regulatory officials and save money for the plant owners. If the regulatory agency has the power to compel the construction of waste treatment plants, and to require periodical records of performance, it should have the same authority to assure good operation.

It is the duty of the designer of the plant to provide the Engineering Staff of the client with sufficient copies of a complete operating manual, for distribution to the Chief Operator and his assistants. This manual should contain a complete description of the plant, the function of each unit in it, reference to the individual instruction manuals of the manufacturers of the various mechanical and other elements and information as to where the operator may obtain advice from any manufacturer. It should contain flow sheets of each line in the waste plant, with numbered references to items in the text. All design factors used in the design of the plant should be given, and instructions for operation under different conditions. The tests, analyses, etc. necessary for satisfactory control should be listed and their importance pointed out. A form for a proper log sheet should be prepared by the designer.

The Chief Operator should read this manual. The best manual in the world is only good if it is used and understood. If he has assistant operators, each one should be given certain responsibilities and the manual should be so prepared that each man can be given a section especially devoted to his operation.

Along with the manual the designer should supply the client with sufficient copies of all individual operating manuals and instructions of the manufacturers of the mechanical elements of the plant. Also complete sets of the drawings of the plant, and manufacturers' shop drawings, etc. should be supplied and kept on hand at the plant.

If chemical analyses are required to determine the results and the perfection of function, the designer should recommend the accepted methods that are to be used. A good and conscientious operator will develop short cuts of his own after the plant is in operation, but the proper basic information should be indicated.

The Chief Operator should be paid well enough to keep his interest and assure that he will always be available and capable of assisting his men when difficulties arise. No plant has ever been built which did not develop some difficulties of one sort or another after operation begins. Many of these difficulties can be laid to improper, faulty, or disinterested operation.

In one recent plant the owner's engineer objected to a certain type of pump because there was leakage at the gland. It was pointed out that this was not a fault of the pump but a matter of housekeeping. However, he ruled against that type of pump in his plant. Another type was selected by him and installed. After the plant was in operation an inspection showed rags wrapped around the gland of the pump he selected. Why? Because the pump was leaking at the gland.

Good housekeeping applies to a waste treatment facility just as strongly as it does to one's own home. Proper lubrication, proper cleanliness are all essential factors in keeping a plant up to proper scale.

In one plant recently a number of pH controls were installed to provide automatic operation of equipment to regulate acidity or alkalinity. The usual electrodes were installed in the proper places. An inspection shortly after the plant was put in operation showed that several of these expensive instruments were not functioning. Why? Because it was too much trouble to clean the electrodes. Demonstration that cleaning was an essential part of the operation had no avail. The client claimed that this method of control was obsolete. Expensive oxidation reduction potential equipment was permitted to become in-operative because some small lines became fouled and required a proper inspection and cleaning.

An essential item in efficient operation is the conscientious keeping of records. In order to judge the efficiency of the treatment methods, it is essential to know at all times, the concentrations of toxic and other elements in the raw waste, at various points in the treatment cycle, and of the final effluent. To know the cost of the treatment records of the amount of chemicals used and other materials must be accurately kept. To be aware of the proper functioning of the apparatus, records must be periodically kept of their condition. In a recent plant treating large volumes of six different types of waste from a plating plant, the log sheet contained 52 important items that would enable the operator or engineer to evaluate conditions in the plant, make adjustments, etc. The total possible items of impotant information that would be useful at different times to tell a certain story totalled 126, but the 52 used on the log sheet give all of the essential information. True, to keep such a log daily requires time and effort on the part of the operators, but the Chief Operator cannot know what his plant is doing unless he insists on the log being kept up to date.

Of course, one cannot demand that an owner operate his plant properly and keep the equipment in proper function. His money has built it and if he cares to waste that investment by providing incompetent operators or lack of supervision, that is his privilege, but it is difficult to see how a large commercial organization will permit an investment of perhaps millions of dollars to rot away because of lack of care and operation.

Now let us get down to the actual study of the best way to treat wastes from a plating plant.

Cyanide Bearing Wastes

These are the most toxic wastes emanating from a metal plating plant. The cyanides are contained in the daily rinse waters from the plating rooms, plus the much heavier concentrations from the periodic dumps of the plating vats. What is the best way to destroy this cyanide?

As there are numerous accepted ways of treating cyanide bearing wastes, the selection of a proper one for a given case depends upon the following factors:

1. The daily volume of the rinse wastes and their cyanide concentration.
2. The periodic dumps and their concentration of cyanide, and their periodicity.
3. The requirements of the regulatory agencies demanding the treatment.
4. The point of discharge of the treated effluent - direct to stream, or to a city sewerage system which ends in a modern sewage treatment plant.
5. The area available for the treatment plant.
6. The willingness of the client to permit study of his processes for inplant changes or use of different methods which may reduce the volume and concentration of toxic elements.
7. The availability of chemical reagents required by different processes of treatment.

Having obtained the data referred to, the next step is to consider the economics of various methods of treatment coupled with the requirements. What may be economic and practical for one plant will not necessarily be the answer for another. Each must be considered on its merits.

Although numerous methods of treating cyanide bearing wastes have been developed, there are at this time about five methods which are recognized and widely used, and which will produce satisfactory results when properly controlled. These are:

1. The gaseous chlorine (alkaline chlorination) method.
2. The sodium hypochlorite method.
3. The integrated method, which is a variation of Nos. 1 or 2
4. The ozonation method.
5. Controlled dilution.

Let us scan each of these independently.

1. Gaseous Chlorine Method

The gaseous chlorine or alkaline chlorination method is today the most used, especially for the larger volumes of waste. This method entails the installation of any one of the recognized chlorine dispensing equipments, known as Chlorinators, Chlorinizers, etc. The chlorine is delivered to the plant in cylinders holding 150 pounds; one-ton cylinders; cars holding 15 one-ton cylinders; and single unit tank cars holding 16, 30 or 55 tons of chlorine. Which of these is to be used depends upon the amount of chlorine to be used.

Assume that we have a problem with 50 pounds of cyanide to be reduced to nitrogen and carbon dioxide per day. While the theoretical amount of chlorine to so reduce one pound of cyanide is 6.83 pounds, this is seldom achieved and it is common practice to install equipment and chlorine supply on the basis of at least 8 pounds per pound of cyanide. Thus, with our 50-pound plant we need a supply of 400 pounds of chlorine per day or operating period. Assume again that we wish to treat this amount of cyanide in a waste plant operating period of eight hours. Therefore, we must have chlorine dispensing equipment and supply capable of supplying 400 pounds of chlorine in eight hours, or at a rate of 1200 pounds per day.

That immediately rules out the 150-pound cylinders, as one cylinder would last only 3 hours and it would mean constant changine of cylinders, requiring much labor, or an inordinate number of cylinders coupled on the line. As the cylinders must be returned when empty, it would be necessary to keep a tremendous number of cylinders on hand to cover possible delays in delivery.

How about ton cylinders? One one-ton cylinder with 2000 pounds of chlorine would last only five days. A number of these could be kept on hand but change would be required at least once per week. For this use one of the standard 15 cylinder cars could be used, but here enters another problem. The railroads will permit a user to retain a car for 30 days, plus a reasonable period above that, but after that demurrage is charged and would become an item in the cost.

A car of 15 one-ton cylinders would last, theoretically, 75 days, or much over the free period.

One of the single unit cars, of 16, 30 or 55 tons? The logical thing would be to select that size car which would need changing only once a month, so if we need a total of 12,000 pounds of chlorine per month, the smallest car is too large, as the 16 tons would last for 80 days, long over the free period. Therefore, in this case it appears that the one-ton cylinders would be the answer.

Naturally, the cost og gaseous chlorine varies according to the containers used. The small cylinders are the highest per pound, the one-tons next, the 15 unit car next, and the single unit tank cars give the lowest delivered cost per pound of chlorine, and consequently the lowest treatment cost per pound of cyanide.

This is based on destruction of cyanide to nitrogen and carbon dioxide. If reduction to cyanates, which are about one-tenth as toxic as cyanide, is permitted, then the theoretical requirements of chlorine would be about 2.73 pounds per pound of cyanide in the raw waste.

With a plant with 200 pounds of cyanide in its waste the picture changes. It would be obviously useless to use the small cylinders, as it would keep a crew busy continuously, as one cylinder would last less than one hour. One-ton cylinders would be uneconomic, as one cylinder would last only about ten hours. The 15-ton car would last about 18 days, which is well within the free period. And the single unit car of 16 tons would last approximately 20 days. In this case a 30-ton single unit car would be justified, as it would last 37 days and the railroad would probably be willing to waive demurrage.

The advantages of the use of the single unit tank are definite. It is used as a reservoir and connected directly on the line to the Chlorinators, therefore, no handling or storage arrangements are necessary. To carry over the period when cars are being changed, at least two one-ton cylinders should be kept on scales, and thrown on the line during the car change period. These cylinders can be refilled from the new car and cut off. If a spare car is on hand, the changeover period should not last over two hours. With two one-ton cylinders, they would carry a load of 250 pounds of cyanide for two hours.

In using chlorinators they must be sized according to the operating period of the plant. If an eight-hour operating period is determined upon, then the chlorinators must be selected of a rated size three times the amount of chlorine required in the eight-hour period. Thus if 1000 pounds of chlorine are required in eight hours, the chlorinators must be rated at 3000 pounds per 24 hours.

When cylinders are used, an area in the plant is required for storage. Hoists and craneways are necessary to handle the full and empty cylinders, scales must be provided, and considerable piping and valving used. Outdoor rails must be provided for loading and unloading, and a constant supply of new cylinders and removal of empty ones provided for.

The cost of chlorine as delivered in the various containers gives a close insight into the economics that must be considered. Say we are using our 50 pounds per day cyanide example; the chlorine demand is 400 pounds per day. The Table No. 1 below shows the relative cost per pound of cyanide for the various containers:

Table No. 1

Effect on Cost of Cyanide Reduction by Various Methods of Obtaining Gaseous Chlorine

Based on Usage of 400 pounds Chlorine Per Day

Type Container	Price Chlorine Delivered	Total Cost Per Day
150-pound cylinder	$0.12	$48.00
One-ton Cylinders	$0.0925	$37.00
15 one-ton cylinders on car (1)	$0.045	$18.00
Single Unit Tank Cars	$0.0358	$14.32

(1) Usage of 3 cars per year

Outside of the bare cost of the chlorine, there is the question of handling the wastes to enable a sensible usage of the material. The effect of lack of care in designing for proper handling is explained earlier in this paper. From the chlorine supply standpoint the 16-ton single unit car would not have sufficient chlorine to handle the load.

Another item in determining the size container to use is the availability of supply. If the supply can be had from a nearby manufacturer with proper delivery facilities, smaller containers can be used than if the supplier must rely on rail deliveries from a distance. In the first case a smaller number of containers need be kept on the job.

2. Sodium Hypochlorite

This is simply another way in which to apply chlorine. Sodium hypochlorite is a solution of about 15 per cent available chlorine to the gallon. Therefore, to obtain one pound of chlorine from sodium hypochlorite it requires 0.8 of one gallon of 15 per cent solution. Thus, to treat one pound of cyanide on the basis of eight pounds of chlorine per pound of cyanide requires about 6.4 gallons of sodium hypochlorite.

The advantage of using sodium hypochlorite is that it requires less equipment and is less dangerous. On the other hand, sodium hypochlorite deteriorates with time and the supply must be tempered with the demand to assure having a solution of proper valency available. One of the leading manufacturers of sodium hypochlorite advises that the solution loses about 3 per cent of its strength per month.

Sodium hypochlorite is delivered in tank trucks, ranging in size from 1500 to 4000 gallons. Thus, for a large plant, storage facilities, transfer equipment must be provided for a constant stream of trucks.

Assuming our 50-pound per day cyanide plant, we would need 320 gallons of sodium hypochlorite. Thus a 1500 gallon truckload would last only 4.3 days and a 4000-gallon truckload only 12 days. With 200 pounds per day, the 4000-gallon truck would last only a little over 3.1 days.

Sodium hypochlorite is more expensive than gaseous chlorine, ranging about 16 cents per gallon delivered. Thus, as against chlorine in one-ton cylinders at $0.0925 per pound, the equivalent 0.8 of a gallon of sodium hypochlorite costs $0.128 per pound, or $1.024 per pound of cyanide converted as against $0.74 per pound for chlorine.

For a small plant sodium hypo does have an advantage as the equipment required is much less expensive than for gaseous chlorine, but a storage tank and adjustable stroke pump is required to distribute to the reaction tank.

Table No. 2 shows the relative costs of treating a given quantity of cyanide per day by the several accepted methods of treatment.

3. The Integrated Method

This method, which makes use of either gaseous chlorine or sodium hypochlorite as a reagent, is simply an installation in the plating line which takes the cyanide bearing solution and treats it as a part of the plating process so that there is no cyanide in the final effluent. Thus, it eliminates a waste problem and the cost of construction and operation of a waste treatment plant. Due to the fact that the system destroys all cyanide before any liquid is discharged, there is no waste problem and the regulatory authorities do not enter into the picture not have any jurisdiction as long as the system functions properly.

The system entails the placement of the treatment tank in the plating line, and therefore the size of plant to which it can be applied is regulated by the area available in the plant for the treatment tank and for the chlorination and control equipment.

The system can be applied in existing plants, if space requirements exist, or can be incorporated into the design of new plating installations. The proponents of the system, which was developed by a prominent specialsist in plating work, state that the cost of the installation is very much less than the cost of waste treatment facilities, which are completely eliminated by the system. The system has been installed at a number of small plating plants, but to my knowledge, no major installation is in operation at this time.

4. Ozone

This method is one of recent development and has just been proven in an operating full-scale plant. The advantage of the ozone process is that no constant supply of chemicals is needed. The plant uses only air and electric current. No buildings are required. Operation is at a minimum, the proponents of the system claiming that one man hour per year is all the attention needed. The equipment can be installed entirely in the open.

This system is the generation of ozone from air by means of electric current. It has been stated by the proponents that two pounds of ozone are required to reduce one pound of cyanide to nitrogen and carbon dioxide. This has been demonstrated by the first and only plant (so far as is known) which uses this system. This is the Boeing Airplane Company plant at Wichita, Kansas.

In a recent letter from the engineers who designed this plant they state, "We do know that all the cyanide is destroyed....the function of the ozone is more than a cyanide oxidant, but also as an oxidant for phenols, oils, sulphites and other organics....we estimate the cost of ozone to run about 14 cents per pound, including electrical enerby at $0.01 per kwh, cooling water and air drying facilities, but not amortization of equipment - claims for operating labor are relatively accurate - little if any operator time is needed for the operation - continuous operation is recommended."

The estimate made by the proponents was that two pounds of ozone would be required to destroy the cyanide. They also estimated that about 13 kwh of electric current were required to produce one pound of ozone. As the air is free, the cost of the ozone would therefore be the cost of the current, plus the amortization and interest on the plant.

The inherent advantages of the use of ozone are manifest; no buildings are required, no attention seems to be necessary, no constant supply of materials is required. But there is another criterion that must be considered, that is, that the ultimate cost of treatment by ozone depends on the operating period of the waste plant. In other words, for a 120-pound-per-day cyanide plant to operate in eight hours, an ozone plant with a capacity of 720 pounds per 24 hours would be required. The estimated cost of the equipment for such a plant would be about $207,000.00 Assuming the use of 240 pounds of ozone at a cost of $0.14 per pound, plus the amortization and interest on the plant at a ten-year write-off and interest at 5 per cent, the total annual cost on a 300-day basis would be $41,130.00. For 120 pounds of cyanide for 300 days, or 36,000 pounds of cyanide per year, the cost per pound of cyanide destroyed is $1.14

Table No. 2

Comparison of Cost of Treating Cyanide by Different Reagents

Based on Reducing 135 Pounds of CN per 24 Hours

300-day per year Operation

Chemical Used	Cost per Year Operating (1)	Cost Per Day	Cost per 1# CN Destroyed	Approximate Investment In Plant
Sodium hypochlorite (2)	$53,531.00	$178.20	$1.32	$37,100.00
Gaseous Chlorine (3)	30,329.00	101.15	0.75	83,100.00
Gaseous Chlorine (4)	48,975.00	163.25	1.21	95,000.00
Ozone (5)	34,124.00	113.40	0.84	151,000.00
Ozone (6)	32,400.00	108.00	0.80	None....

All above based on 10-year write-off of equipment

(1) Includes amortization and interest, labor, current, etc.

(2) Based on cost of $0.16 per gallon delivered, 6.4 gallons per pound of cyanide.

(3) Based on cost of chlorine in tank cars at $0.035 per pound CL and 8 pounds per pound of cyanide. Cost includes necessary lime, current, amortization and interest on investment.

(4) Based on use of one-ton cylinders with chlorine at $0.0925 per pound.

(5) Based on ozone generation plant to supply 270 pounds of ozone in an operating period of 24 hours.

(6) Based on ozone equipment manufacturing company furnishing and installing complete equipment at his expense and charging client a metered charge for pound of ozone of plant capacity, not actual amount used. Thus, if a plant to supply 270 pounds of ozone is installed on this basis to supply that amount in 8 hours, the installed ozone generator rated capacity would be 810 pounds per 24 hours and the metered charge would be based on this.

This requires an investment of the amount shown, and the manner in which this is handled as concerns amortization and interest is governed by the financial policy of the dompany using the system. If the plant is purchased, the investment is a capital addition and becomes an asset. Amortization and interest and operating costs can be charged against plant overhead.

An unusual and interesting alternative to the purchase of an ozone generating plant has been developed by one of the companies manufacturing the equipment. This is known as the "metered ozone" system. In this case the company manufacturing the equipment furnishes all the equipment, installs it, gives supervisory operation service and charges the client on the basis of the ozone capacity of the plant. This is figured on a ten-year contract basis, and the price per pound of ozone charged the client is based on the write-off of the equipment in ten years, plus operating costs and profit for the manufacturer. Table No. 2 shows how this works out on the basis of 24-hour operation of the waste treatment plant.

In this case of the "metered ozone" system, if the waste plant operation is based on eight hours per day, then the ozone plant must be able to deliver the required amount in that time and the rated capacity of the ozone generators must be three times that amount per 24 hours. In such a case the metered charge is based on the cost of the plant for the rated 24-hour capacity and throws the picture out of level. Thus, if a plant to supply 100 pounds of metered ozone at a rate of 24 hours per day, gives a customer rate of $0.30 per pound of ozone used, the plant, to deliver that same amount of ozone in eight hours, would have a 24-hour capacity of 300, and the metered rate would be based on that capacity.

The main advantage of the "metered rate" plant is that the client makes no investment whatever and the total charge for metered ozone can be charged into overhead. This, in many cases, has an appeal for those companies which might not wish to make heavy capital investments. The economy of this system rests in 24-hour operation.

Operating Period of the Waste Plant

This is primarily a study in economics and expediency and no general rule can be established. Each case must be considered on its own merits.

Whether to operate a waste treatment plant 24 hours per day, 16 hours, or eight hours (one shift) is a matter for determination by the designer coupled with the desires of the plant owner or operator.

To treat wastes over the entire 24 hours will entail the least cost for initial installation, but the operating cost will be materially higher as it will be necessary to have three complete shifts of operating staff. As labor in the United States and other American countries is the main item of cost in all industrial operations, this cost may exceed all other considerations.

Let us assume that a given plant requires a force of four men to operate it, one Chief Operator and three assistants. With the Chief Operator at $3.00 per hour and the three others at $2.50, this amounts to $84.00 per shift. Three shifts total $252.00 per day for operation labor. In a recent case it was figured that the cost of equipment for 24-hour operation would cost $54,453.00 and three-shift operator cost for a 300-day year would be $75,600.00.

For 16-hour operation the initial cost of the plant would be $68,010.00 but labor would only be of the order of $50,400 per year. Thus a net saving of $25,200 per year would be achieved. For eight-hour operation the initial plant cost would be $79,600.00 and the annual labor bill only $25,200, or roughly one-third of the labor bill for the 24-hour operation, and the net saving over 24-hour operation would be $50,400.00 per year. These figures are approximate only and would vary for each job and locality.

However, the main benefit in having eight-hour or 16-hour waste plant operation is the safety factor gained. In a plant designed for 24-hour operation, the units could be made large enough to have a safety factor over the estimated actual maximum volume of wastes, but this must have a limit and once the designed maximum is exceeded there is no leeway for unexpected loads. With 16-hour design there is a 50 per cent overload capacity and with the eight-hour plant operation schedule there is a 200 per cent overload capacity. Thus in these cases the plant will be able to handle large overloads by simply operating for a longer period. Another advantage of the shorter operating period is that there is less wear and tear on the equipment and consequently less maintenance. Also in the down period there is time to make minor adjustments and repairs, whereas with 24-hour operation the plant must be completely shut down.

The value of duplicate holding tanks is well established. If there is but one holding tank for a given waste, the waste to be treated must be drawn from it while it is filling and waste concentrations will vary, thus necessitating constant watch of controls to adjust reagent needs to the changing demand. This entails more attention from the operators and more chance for trouble.

With two holding tanks, each with a capacity equal to one day's waste volume, the tanks are alternated in use. One tank is being filled and agitated at all times so that the wastes are uniform in concentration. Nothing is drawn from the filling tank, but the wastes being treated are drawn from the tank filled the previous day. The wastes are thoroughly homogenized and after the operator makes his check before starting the day's operation, he can then set his controls and as the wastes will be of uniform concentration and volume throughout the treatment period, he is relieved of constant attention and adjustment. Duplicate tanks increase the cost of the plant but it is believed that the benefits are well worth the cost. Other than that if the holding tanks are in duplicate, the plant may be shut down for two days for repairs without necessitating the by-passing of raw wastes to the stream or sewer.

<u>Analyses</u>

In order to ascertain what degree of treatment is needed for a given waste and to check on the final effluent which must meet certain requirements, it is essential that constant analytical checks be made. For the cyanide and chromium tests, using accepted laboratory methods and technique, one test for cyanide concentration occupies the laboratory technician for almost two hours. Thus during one shift one laboratory man can do only four such tests. For a plant where samples are taken of the effluent every hour by a city bureau, serious inefficiencies in effluent could occur and not be caught in the plant. Quicker and more assured methods must be considered.

Recent developments in colorimetric determinations have shown that automatic continuous analyzing equipment can be had which relieves the laboratory staff of these tedious hand-to-mouth methods and can make the tests in a matter of minutes and record the result on a chart for permanent record. The advantage of releasing the laboratory technician time for other necessary tasks can be understood as well as the definite printed record which would be accepted by the State or City authority as authentic proof that the plant was operating satisfactorily.

Up to this time the equipment for this new conception in testing technique is expensive, but this cost will undoubtedly reduce as the demand for such instruments grows. At this time several companies can offer automatic, continuous analyzing systems for between $3500.00 and $5000.00. This may seem high, but when it is considered that it will save the time of at least one technician in a large plant, this saving alone will pay for the automatic equipment in one year or less. It pays to investigate this advanced method.

Conclusion

The considerations discussed herein apply equally strongly to the treatment of other wastes from plating plants, such as hexavalent chromium, oily wastes, acid and alkaline wastes, but due to the time element provided it is not possible to give each of these specific mention. But the same degree of attention must be given to each.

INDUSTRIAL WASTE CONTROL IN GENERAL MOTORS CORPORATION *

- by -

David Milne, Supervisor
Materials and Processes
Production Engineering Section
General Motors Corporation

I have been asked to provide you with a review of activity in industrial waste control at General Motors Corporation and to describe some of the things we are doing in this field. I would like to go a little further than this and discuss with you an approach to waste control which we feel to be particularly valuable, that is, the insistence on conservation of materials as a primary feature of the waste control programme. This paper will review, then, the general history of waste control activity in General Motors, the development of our philosophy towards solution of waste control problems, and the conservation techniques found useful to the Corporation in this field.

HISTORY

Treatment Plants

The first waste treatment equipment used in the Corporation was built in 1934 and was designed to destroy concentrated waste cyanide from a plating operation. At that time little consideration was given to the need for treatment of the rinse waters leaving such operations. Treatment was confined almost entirely to the much stronger processing solutions. (Figure 1) The treatment equipment was simply a discarded plating tank, modified to permit addition of acid, air agitation, and exhaust through a 60 foot stack. The cyanide was acidified with sulfuric acid, agitated with air, and the released hydrocyanic acid gas blown through the stack to the atmosphere. The treated solution was then released to the nearby river. Control of this process was based on chemical analysis of the treated solution.

The next treatment plant to be established in the Corporation gathered all of the wastes being discharged from the plant into two large settling basins (Figure 2). This plant was built in 1938. The intention was to accumulate all of the wastes in one spot and to neutralize these wastes to a pH value between 6 and 8 by the addition of alkali or acid as needed. Cyanide wastes were also expected at this plant and an expensive treatment chamber was built to take care of these wastes by acid destruction. The neutralization chamber was especially designed for this job, and I believe that it was the first of its kind to be built for this specific purpose. This cyanide destruction system was never used as conditions never developed which would make discharge of the concentrated cyanide necessary. The acid and alkali neutralization system worked quite well and is still in operation at this installation.

A few years later, in 1941, another plant of the Corporation found that installation of waste treatment facilities was advisable in view of increasing production loads. This plant also did a large amount of plating. A survey of the situation indicated that regulated discharge and dilution in the waste water from the nearby town would provide an overall effluent with concentrations considerably lower than the limits imposed by the State. (Figure 3) This controlled discharge system was installed as a series of lagoons, and is still in operation. This system requires careful supervision to make sure that release of the concentrated wastes proceeds at the proper rate and in proportion to the more dilute rinse and cooling waters being discharged from the plant.

In the late 1940's, and throughout the 50's, the Divisions of the Corporation built many treatment plants and installed several waste conservation and recovery devices. One of the earliest of these was built by a plant which made use of the sewer system of a large city to dispose of its wastes. Some highly concentrated cyanide wastes from plating solutions and heat treating operations were witheld from discharge to the sewers and a simple chlorination treatment set up. (Figure 4) This consisted of a tank provided with a mixing device, into which chlorine gas could be fed directly from a cylinder. The system was gradually improved upon, (Figure 5), mainly to the extent of adding safety devices and the eventual replacement of the chlorine gas with a sodium hypochlorite solution. This simple device is still in use, and, coupled with close laboratory control, is perfectly satisfactory for the conditions existing at the plant.

The first waste treatment plant in the Corporation to be tailor made to handle specific and segregated wastes was built in 1947. (Figure 6) This plant was the result of a careful survey of production operations, and was designed to receive segregated flows of acids, alkalis, oils, and chromates. Oil emulsions are broken with ferrous sulfate and lime, and chromates reduced with ferrous sulfate or waste pickling acid. Sludge produced in this plant was discharged to a lagoon, and permitted to dry in the open air.

Treatment plants since that time have tended to become much larger and, of course, much more expensive. One of the largest of these, which handles an exceedingly complex operation of the Corporation in one of its largest manufacturing plants, cost in excess of $3,500,000. The plant is designed to handle oily wastes at a flow rate of 1600 gallons per minute for a two shift operation. (Figure 7) Treatment facilities include holding tanks of 750,000 gallon capacity, clarifiers holding 100,000 gallons, waste oil tanks holding 100,000 gallons, and sludge filtering and drying systems in proportion.

The control building itself (Figure 8) is as large as some small manufacturing plants, being 180 feet long, 28 feet wide, and three stories high plus basement. This building houses the control equipment, pumps, chemical storage and feeding equipment, laboratory, and vacuum filters used for sludge removal.

One of the most recent waste treatment plants built by the Corporation (Figure 9) was designed to handle an overall storm sewer flow of 1900 gallons per minute. Layout of the plant, which sprawled over about 70 acres, made it impractical to try to segregate all wastes. Certain troublesome areas were isolated, however, and piped directly to specialized treatment equipment in the waste control plant. In general, this installation treats plating wastes and oily storm sewer water, and is placed directly across the main storm sewer flow from the manufacturing plant. It uses conventional treatment methods, and operates over three shifts per day, seven days per week.

Other huge treatment plants have been built by the Corporation, (Figure 10) usually in conjunction with waste recovery processes. (Figure 11) All of these reflect not only the size of the manufacturing operations so protected, but the cost which has to be added to the final product. Altogether the Corporation has built waste treatment, recovery, or control facilities in over 95 plants at a cost of about 40 million dollars for initial construction. No attempt has been made to estimate what the additional cost of maintenance, chemicals, power, and labour has been over the many years these plants have been in operation.

At this point I would like to touch on certain other activities of the Corporation in the waste control field. It has been recognized for many years in General Motors that much duplication of effort could be avoided by close co-ordination and exchange of information between Divisions to assure this co-operation. Several technical committees have been organized in various fields of engineering and manufacturing. It was, therefore, decided that a committee be organized to study the field of waste control and help the Divisions of the Corporation solve their individual problems. The General Motors Industrial Waste Treatment Committee was established in 1945 under the supervision of the Manufacturing Staff and is still operating as an advisory group to the Corporation.

The committee had been in existence only a short time before it was realized that the main effort of the Corporation should be in the direction of control of wastes rather than treatment. Therefore, the name of the committee was changed to the Industrial Waste Control Committee to reflect this broadened interest.

As part of its activities, the committee secured speakers from various parts of the country who had either engineering experience in the field of waste control or who could express the viewpoint of the regulatory agencies. The advice of these men was distributed to the Corporation in the form of bulletins and reports, and also in the reports of the many meetings held by the Committee.

At the same time the committee visited existing waste treatment plants to secure more background on what was being done in the field. As a result of the activities of this committee, a strong background of experience and engineering "know-how" was developed which is proving invaluable in solution of waste problems in the Corporation. In addition, and on the advice of the committee, the Corporation established a policy of complete co-operation with regulatory authorities in the states and in the federal government to make sure that these men knew exactly what was going on in the Corporation in this field. This policy has helped tremendously in securing an atmosphere of co-operation, good will, and mutual understanding. We don't believe, however, that the existence or non-existence of state or federal regulations should have any effect on application of waste control measures in the Corporation. As a matter of fundamental principle, we believe that Corporation plants should not pollute the waters of the community and that each organization should take every step within reason to be a good citizen of the community in which it does business.

Since that time the Central Office activities of the Corporation in the field of waste control have proceeded in two directions. First, the Production Engineering Section (now a part of the Process Development Staff) provides an advisory service to the Divisions in the technical and organizational areas of waste control. It is also active in the encouragement and stimulation of the Divisions toward a realistic approach to the waste control problem. Through the Industrial Waste Control Advisory Committee, made up of waste control experts from several of our Divisions, the Production Engineering Section arranges for group advice on the waste treatment problems in the Corporation. We have men on this Advisory Committee who have had several years of experience in the design, construction, and operation of industrial waste treatment plants in the metal working field. The advice of these men is invaluable toward making sure that new installations are completed at the lowest cost and with the most likelihood of successful operation.

In general, the Production Engineering Section advises the Divisions to follow a definite sequence in planning its waste control program. This sequence includes a survey of the entire water usage and waste situation in the plant by a competent outside consultant, review of his findings and recommendations by the Industrial Waste Control Committee (which includes suggestions for modification, conservation activities, and improvement based on Corporation experience) and design and construction by an engineering organization such as Argonaut Realty Division.

The second area of Central Office activity is in the work of the Argonaut Realty Division as an industrial waste plant design and construction agency. This Division undertakes to design and supervise construction of the industrial waste treatment plant finally decided upon by the Divisions in consultation with the Industrial Waste Control Committee and outside consultants.

PHILOSOPHY OF WASTE CONTROL

Over the years there has been a gradually changing approach to the entire problem of industrial waste control, both in the Corporation and in the field. The first attempts at waste control were to isolate those solutions which presented the most serious problems, and to treat them individually by whatever treatment process was available at that time. Treatment of the concentrated cyanide solutions already mentioned is a good example of this approach.

Shortly after this, the concept of overall treatment of plant wastes came into being and at that time huge collection basins were established to intercept all of the waste liquids leaving the plant so that they could be treated as one solution. Obviously, where especially objectionable materials were included, an attempt was made to handle these separately as the most efficient means of taking care of the problem. As this concept began to be applied to larger and larger manufacturing operations, it became obvious that the cost of such installations was getting out of hand.

A more efficient method for handling these wastes was then developed. In this concept, the initial survey started in the plant at the process under consideration. Upon completion of the survey, a careful review was made of each of the wastes being discharged.

This review brought out several things. First of all, was it necessary to treat this particular waste? In many cases it was found that large volumes of relatively uncontaminated cooling waters and rinse waters were being passed through waste treatment systems with the effect of simply diluting the wastes to be treated and reducing the efficiency of the treatment process. Again, were the wastes capable of being treated for economical recovery of the waste materials contained in them? It was found that in some cases expensive chemicals were being lost down the sewers. By the application of chemical engineering know-how, techniques were developed to recover these materials at tremendous savings to the manufacturing operation (figure 12).

An additional consideration was in the process itself. Could the process be so rearranged that the materials being used need not be wasted or, if some waste was necessary, could they be lowered appreciably in concentration?

Another possibility lay in the fact that certain chemical materials being discharged could act as neutralizing agents or treatment agents for other wastes, resulting in relatively harmless solutions.

It was found that engineering at the source of the waste could frequently result in savings in the size of the treatment plant necessary for these wastes, and that, in a few cases, it was even possible to eliminate the need for a treatment plant.

It was also found that by using this approach, considerable advantage could be gained by transporting these wastes in individually assigned piping systems to the waste treatment plant, maintaining segregation of these chemicals either individually or by classes. All of this resulted in better designs of treatment plants and in more economical and more efficient operation.

In order to illustrate what can be done to cut down wastes, I would like to outline briefly ten general steps which may be taken and which have been applied by our plants at considerable benefit to their operations.

1. Establish better engineered methods for rinsing plated parts (fog, counterflow, lower concentrations, etc.)

2. Check the possibility of substituting a chemical process (such as molten alkali cleaning in place of pickling) which will not result in an objectionable waste.

3. Try to find a mechanical process to take the place of a chemical process which produces an objectionable waste (abrasive cleaning in place of pickling etc.)

4. Check the possibility of reconditioning or purifying solutions on a regular basis so that the life of the solution may be extended.

5. Where a concentrated solution must be replaced from time to time because of the buildup of undesirable materials, see if removal and replacement of small quantities each day will keep the solution in satisfactory condition.

6. Where certain isolated processes contribute the majority of the serious pollution load from the plant, try to separate these wastes from the entire waste flow and handle them separately.

7. Find out if the materials you are wasting are of any use to a neighbouring industry (or vice versa), either as a means of neutralizing its wastes or even as a raw material for its process.

8. Be sure to check with local officials as to exactly what treatment is expected of waste materials entering the sewers.

9. Be sure that cooling waters are conserved as much as possible.

10. Establish tight control over the waste solutions in the plant. Let the operators of your processes know the value of what is going down the sewer, and what it will do to the sewers, the sewage treatment plant, or the river or lake receiving it.

The above should serve to emphasize our basic approach to the waste treatment problem -- if you don't waste it, you don't have to treat it.

FUTURE

We might do well to spend a little time looking at some of the problems we still have ahead of us in waste control.

First, we need to develop better conservation methods. We have some excellent examples of conservation engineering in the areas of plating waste control and the recovery of oils from machining operations. These are still not good enough and we expect that better methods will be developed as time goes by.

One of our greatest areas for improvement is in good housekeeping in the plants and this is an area which can be taken care of at very little cost. Conservation of waste materials can easily take the form of substitution by other processes which will provide us with equal or better quality of product at equal or less cost. There are many ways in which this can be done if a little ingenuity is exercised in our manufacturing operations and in the direction of our manufacturing research.

Another area for future work is the development of less expensive waste treatment processes. This is one of the problems which prevents many organizations from stepping up to the job of waste control. Many of our present treatment methods are exceedingly costly and as this must be included in the cost of manufacturing the product, the waste treatment process must eventually be paid for by the consumer. There has been some fear that this added cost would result in competitive disadvantage to the person who is conscientious in meeting his community obligations in providing for complete treatment of his wastes.

One of the ways in which this can be overcome is to make sure that less costly treatment processes are developed. For instance, most of our waste treatment processes, at least in the metal working field, are based on purely chemical considerations. We have made little progress in exploring the possibilities of other methods of treatment, such as the biological methods. There is considerable evidence, for instance, that cyanides can be treated by biological means by the development of certain fungi which live on this material. Some research is being conducted on this possibility now, and its economic advantage can readily be seen. We are now treating cyanides by chlorination which is an expensive process. The development of a biological treatment method would presumably cut the cost of this treatment considerably.

We must also develop less costly physical installations for treatment of wastes. Our present waste treatment plants are characterized by huge settling and reaction basins. Faster and more efficient destruction and separation techniques must be worked out to insure the development of smaller and less costly package treatment systems.

Finally, one of our most troublesome problems is that of handling the sludges which develop as a result of waste treatment. We have found that most waste treatment plants underestimate the volume of sludge which will be produced as a result of treatment operation. Handling of this sludge is in most cases an exasperating and expensive problem. In the past, we have depended on lagoons (Figure 13) for disposition of these sludges but have come to realize that this method is completely unsatisfactory. Many of the sludges obtained from metal working operations are extremely difficult to handle on the drying beds (Figure 14), and do not dry in a manner which will permit their easy removal at a later date. In some cases we have been able to secure drying of sludge where carefully engineered sludge drying beds have been installed. (Figure 15)

We have used vacuum filters of various types which have given indifferent results. We are considering the use of incinerators to dispose of these sludges. An additional approach has been in reviewing the treatment process itself with the thought of selecting methods which produce the least amount of sludge of the highest density. Many of our Divisions are actively working on this problem as it presents a serious and costly area of waste control activity. We hope to have the problem well in hand within the next few years but so far have not been able to determine which method will be the most convenient and most economical for our purposes.

CONCLUSION

The problem of control of industrial wastes will be with us as long as we conduct manufacturing operations. This being the case, it is to the advantage of industry to learn not only how to handle its wastes, but how to handle them in such a way which will result in minimum expenditures for equipment, chemicals, and labour, and if possible, so as to actually lower the cost of operations. As noted above, the hard fact of the situation is that the cost of treating an industrial waste becomes part of the cost of manufacturing the product, and it must be paid for by the consumer. We in General Motors are as fully aware of this situation as anyone else, and our efforts have been directed towards lowering this cost.

This has not prevented us, however, from installing the waste treatment plants believed necessary to fulfill our obligations to the surrounding communities. As shown above, many expensive and complex treatment plants have been built by the Corporation.

This paper has attempted to describe, in the very broadest terms, the progress made towards solution of waste control problems at General Motors. While we certainly do not have all our problems in hand, we believe we have shown a great deal of progress in this area, and in the years to dome we expect to accomplish a lot more.

FIGURES

1. First cyanide waste destruction system built by the Corporation (1934).
2. Waste accumulation basins for neutralization and settling of wastes (1938)
3. Lagoons used for regulated discharge of concentrated and dilute plating wastes and cooling waters.
4. Simple tank and stirring arrangement set up for chlorination of waste cyanides from heat treatment operations.
5. Improved cyanide destruction system incorporating safeguards surrounding tank and better handling equipment for waste cyanides.
6. Waste plant built in the Corporation for treatment of specific and segregated wastes (1947).
7. Large holding tanks, oil storage tanks, and primary clarifiers at a large oily waste treatment plant.
8. Control building for large oil waste treatment plant.
9. Large oil waste and plating waste treatment plant handling 1900 gallons per minute storm sewer flow.
10. Artist's drawing of waste treatment system for plating wastes and oily wastes from a large automotive manufacturing and assembly plant.
11. Photographs of installation shown in artist's conception in "10".
12. Example of chemical savings by application of evaporation techniques to chromic acid and nickel rinses from plating systems.
13. Typical lagoon used for settling sludge from a plating waste treatment plant.
14. Appearance of sludge from pickle liquor neutralization after several months of drying.
15. Appearance of sludge in properly engineered drying beds.

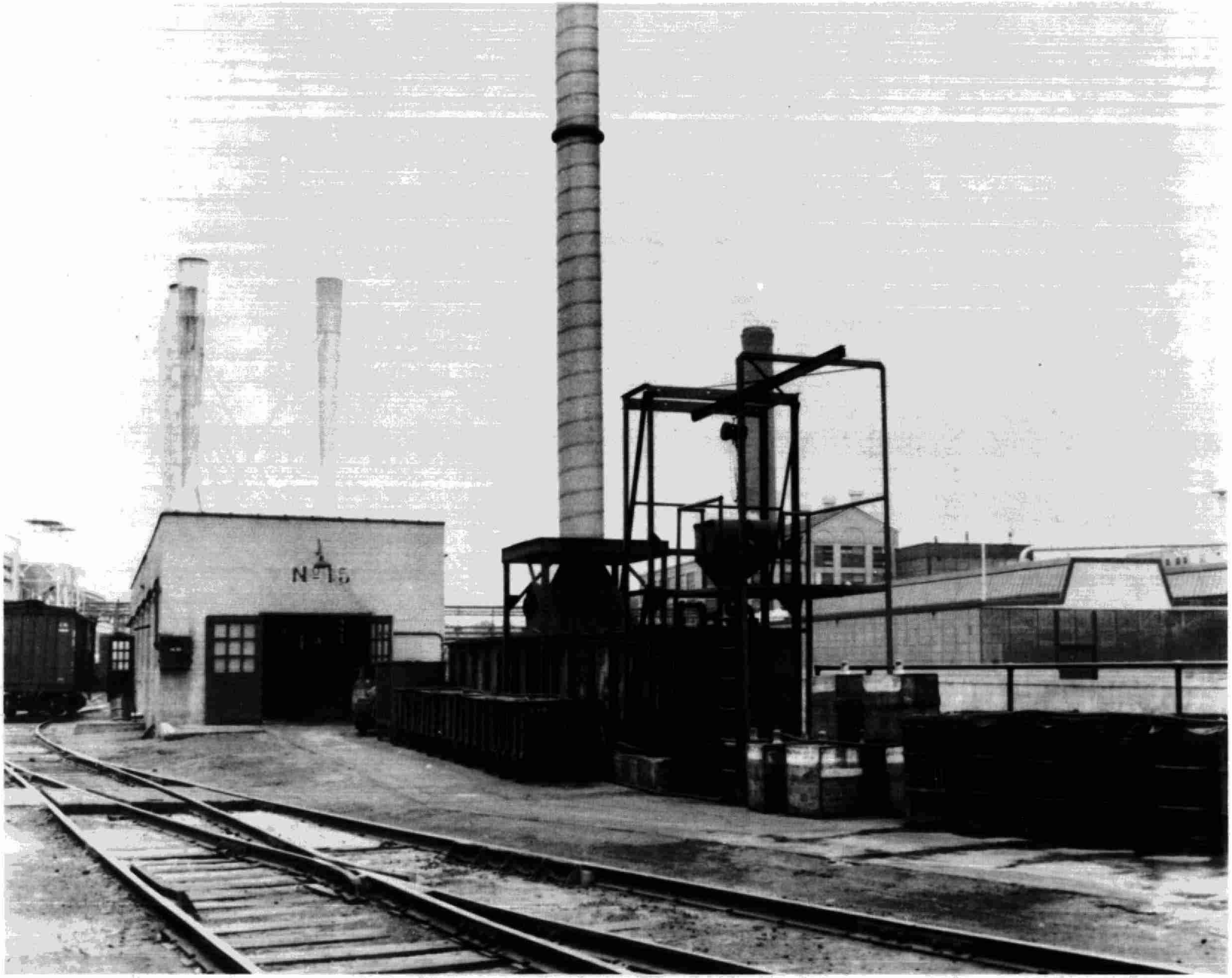


FIGURE 1—FIRST CYANIDE WASTE DESTRUCTION SYSTEM BUILT BY THE CORPORATION (1934)

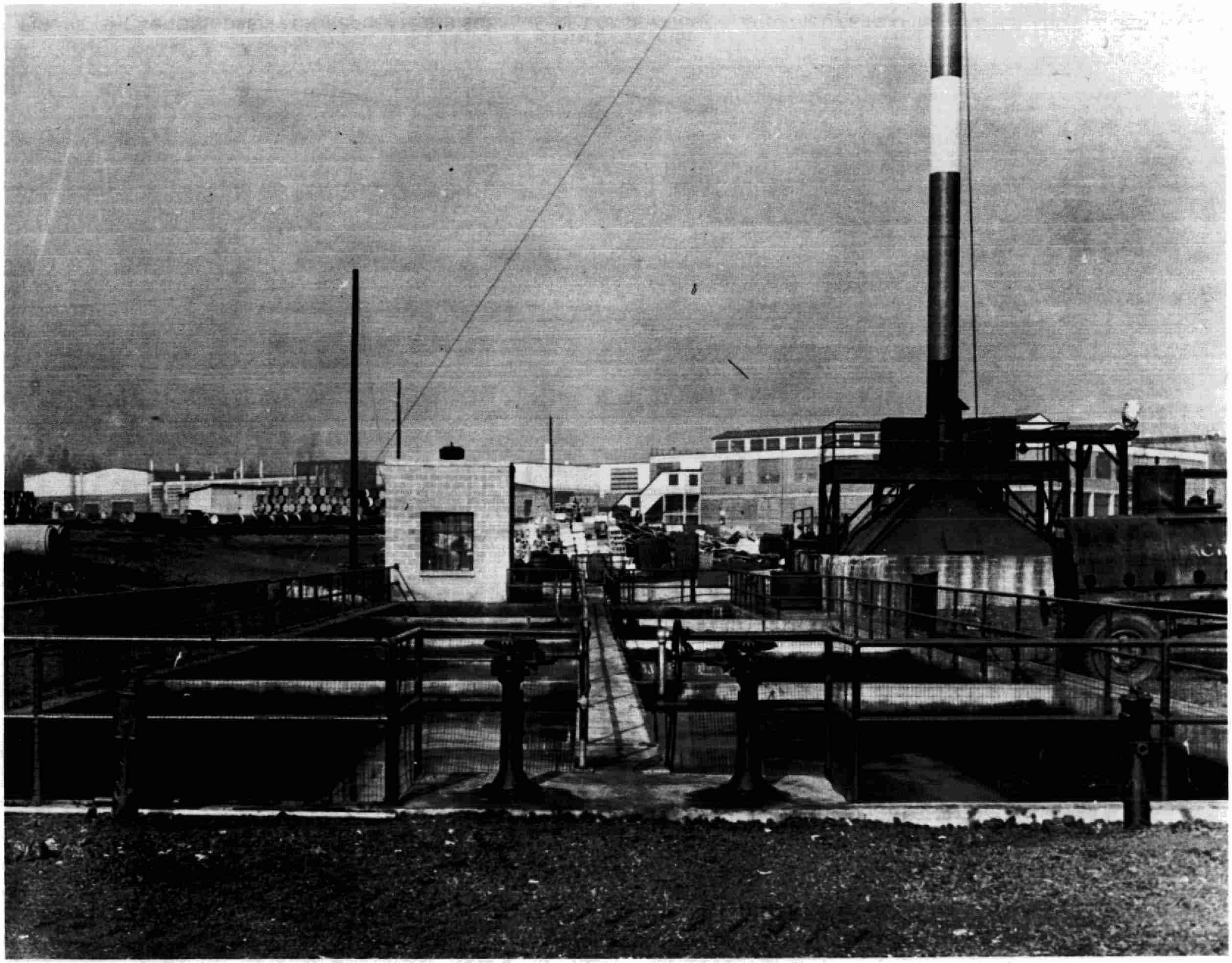


FIGURE 2—WASTE ACCUMULATION BASINS FOR NEUTRALIZATION AND SETTLING OF WASTES (1938)

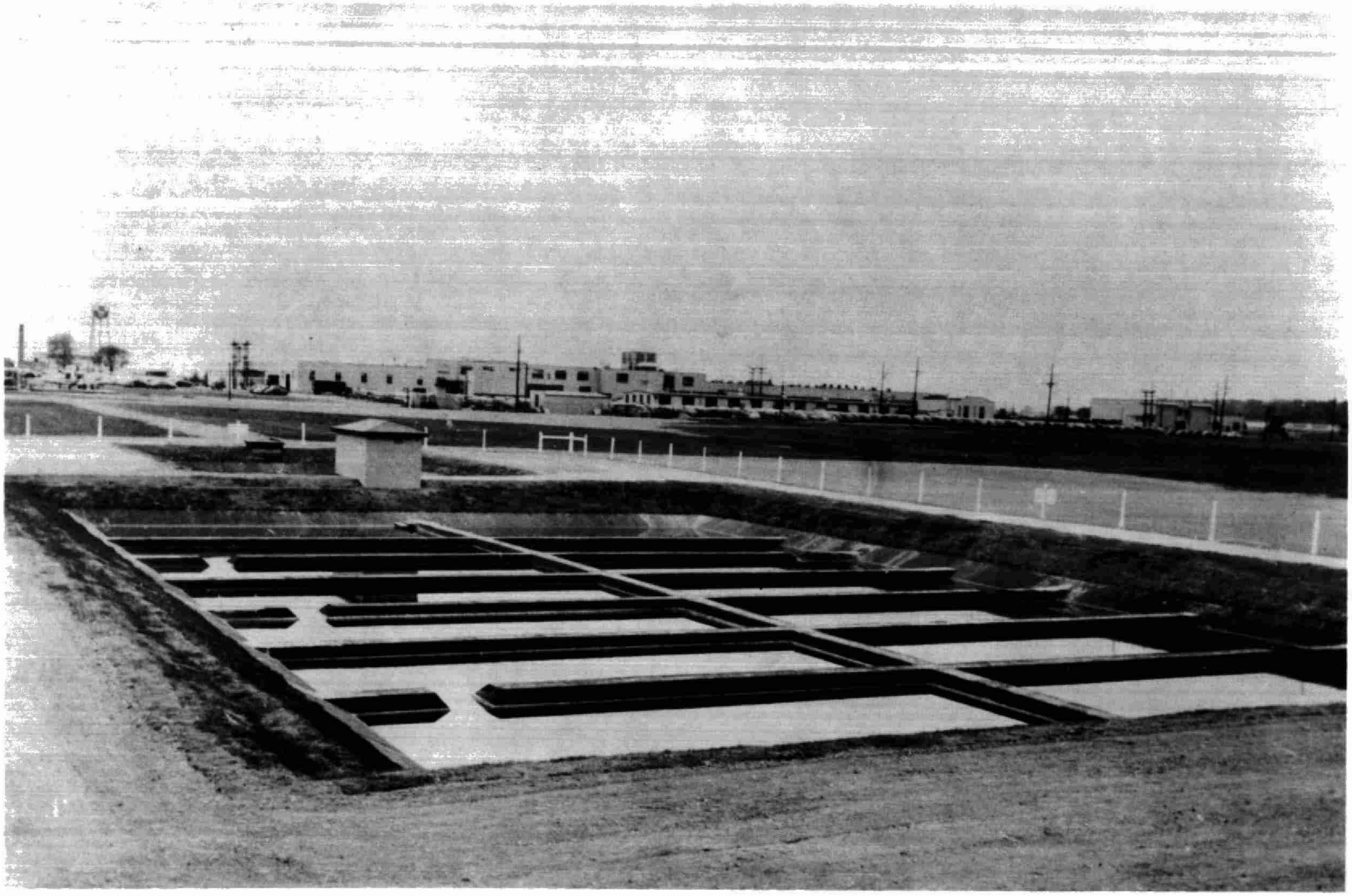
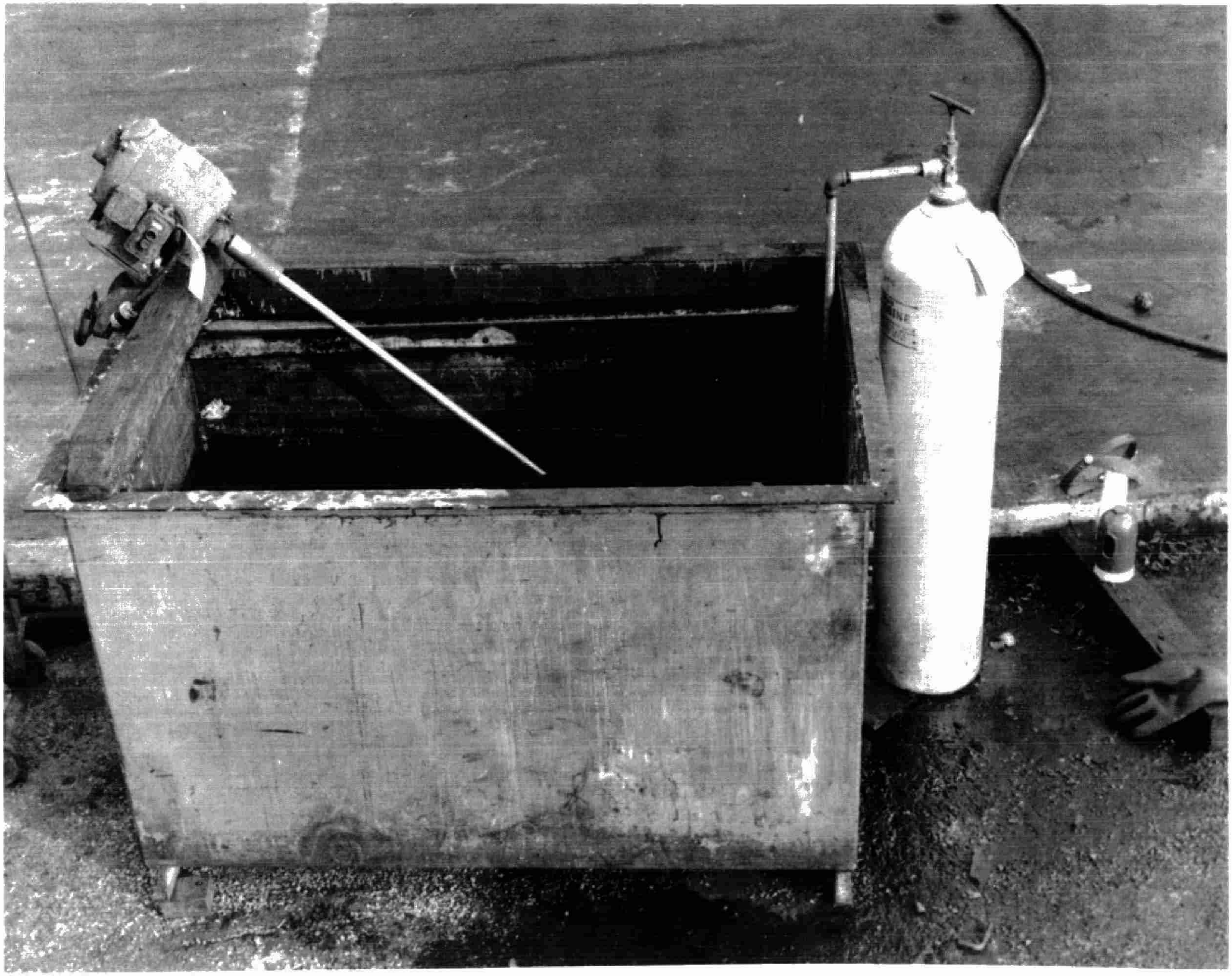
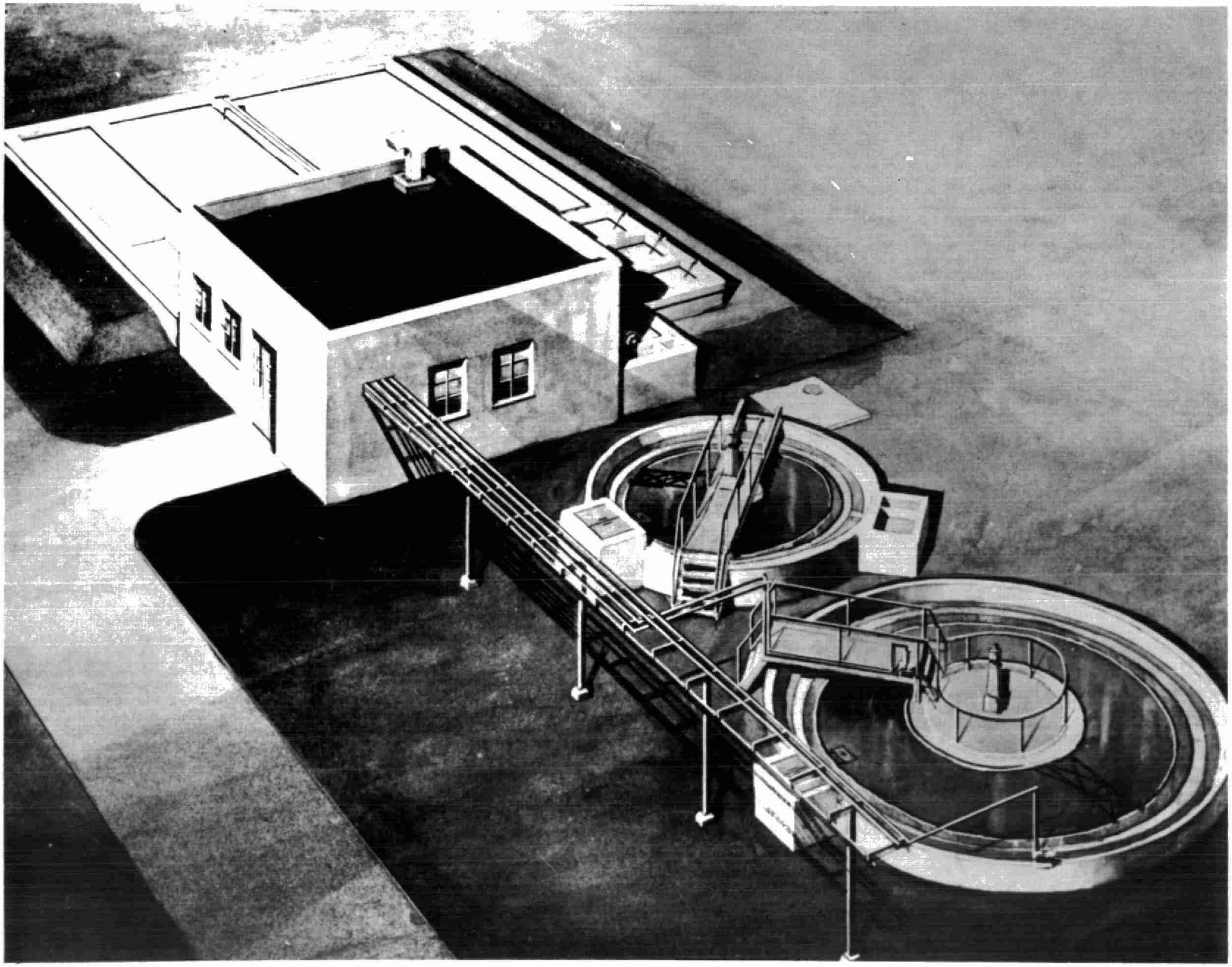


FIGURE 3—LAGOONS USED FOR REGULATED DISCHARGE OF CONCENTRATED AND DILUTE PLATING WASTES AND COOLING WATERS



— FIGURE 4-SIMPLE TANK & STIRRING ARRANGEMENT SET UP FOR CHLORINATION OF WASTE CYANIDES FROM HEAT TREATMENT OPERATIONS —

FIGURE 5, IMPROVED CYANIDE DESTRUCTION SYSTEM INCORPORATING SAFEGUARDS SURROUNDING TANK AND BETTER HANDLING EQUIPMENT FOR WASTE CYANIDES



— FIGURE 6, WASTE PLANT BUILT IN THE CORPORATION FOR TREATMENT OF SPECIFIC AND SEGREGATED WASTES — (1947) —

FIGURE 7, LARGE HOLDING TANKS, OIL STORAGE TANKS & PRIMARY CLARIFIERS AT A LARGE OILY WASTE TREATMENT PLANT

FIGURE 8, CONTROL BUILDING FOR LARGE OIL WASTE TREATMENT PLANT

—— FIGURE 9, LARGE OIL WASTE AND PLATING WASTE TREATMENT PLANT HANDLING 1900 GALLONS PER MINUTE STORM SEWER FLOW.

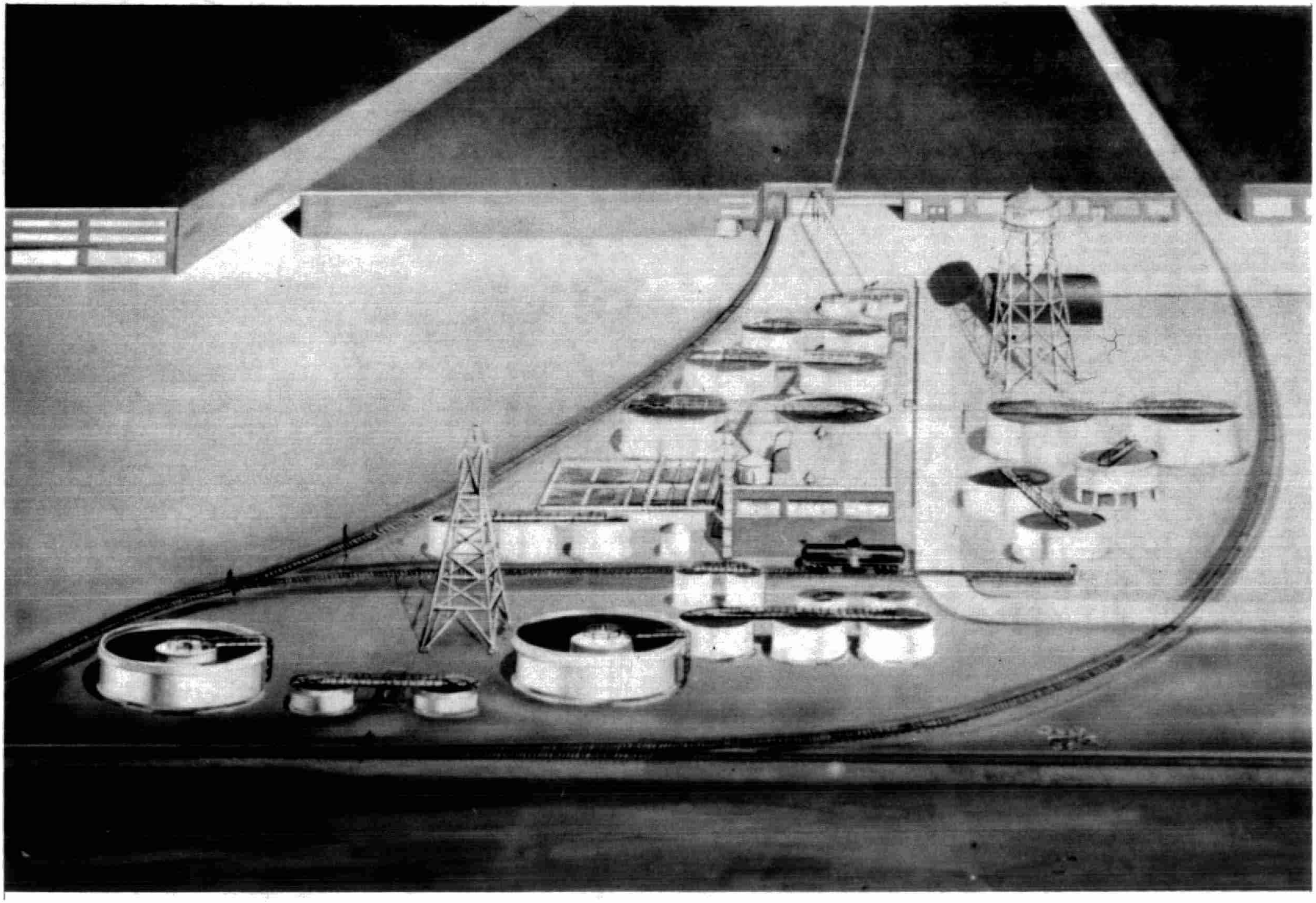


FIGURE 10, ARTIST'S DRAWING OF WASTE TREATMENT SYSTEM FOR PLATING WASTES AND OILY WASTES FROM A LARGE AUTOMOTIVE MANUFACTURING AND ASSEMBLY PLANT

FIGURE II, INSTALLATION DETAILS OF TANKS IN THE TREATMENT SYSTEM SHOWN IN FIGURE IO

CHEMICAL SAVINGS BY RINSE EVAPORATION

PLANT A	LBS/DAY	COST/LB	SAVINGS/DAY
VACUUM			
CHROMIC ACID	300	30 ¢	$ 90.00
ATMOSPHERIC			
NICKEL SULFATE	200	32.5 ¢	65.00
NICKEL CHLORIDE	30	40.5 ¢	12.00
			$ 167.00
PLANT B			
VACUUM			
CHROMIC ACID	690	30 ¢	$ 207.00

FIGURE 12, EXAMPLE OF CHEMICAL SAVINGS BY APPLICATION OF EVAPORATION TECHNIQUES TO CHROMIC ACID AND NICKEL RINSES FROM PLATING SYSTEMS

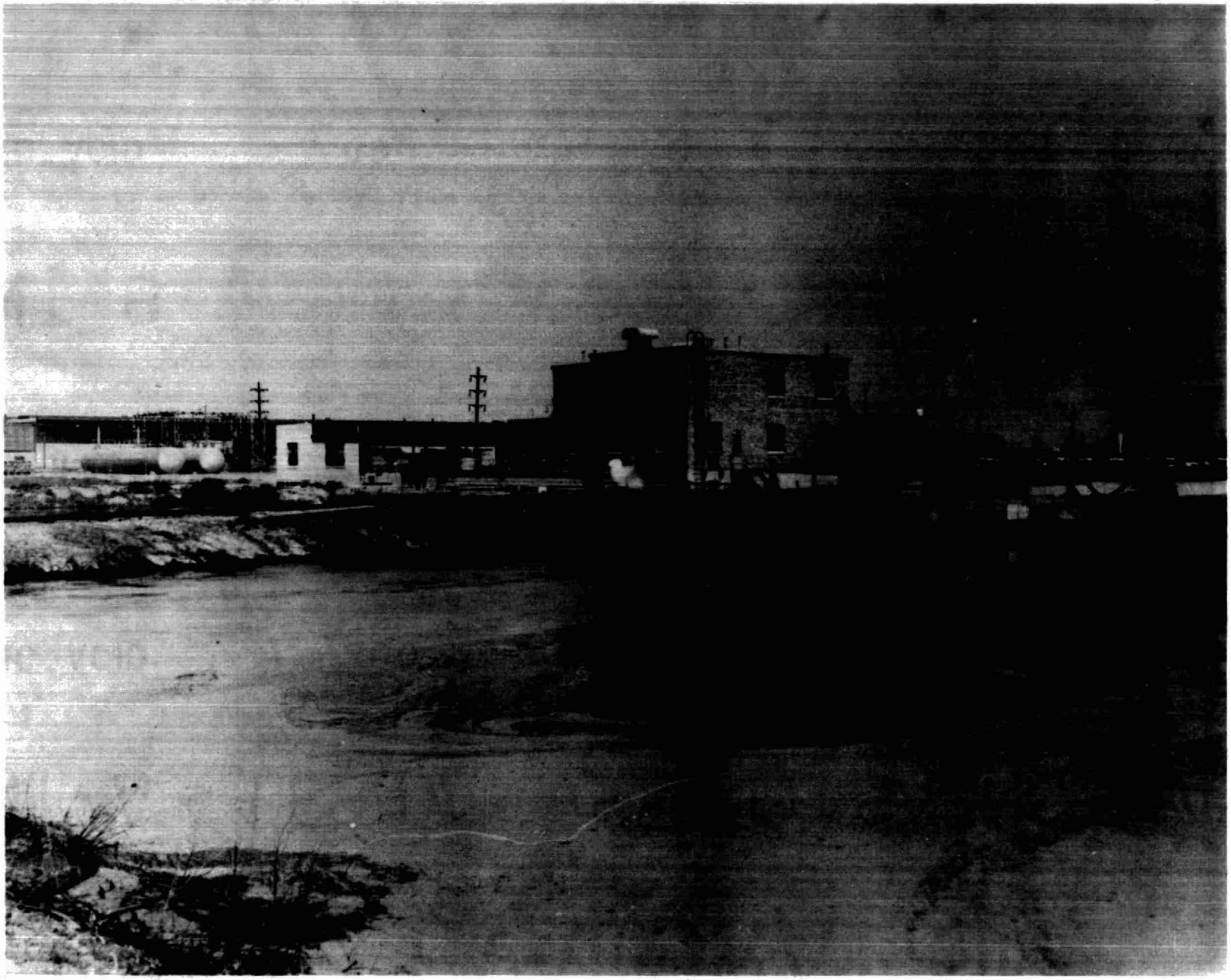


FIGURE 13, TYPICAL LAGOON USED FOR SETTLING SLUDGE FROM A PLATING WASTE TREATMENT PLANT

FIGURE 14, APPEARANCE OF SLUDGE FROM PICKLE LIQUOR NEUTRALIZATION AFTER SEVERAL MONTHS OF DRYING

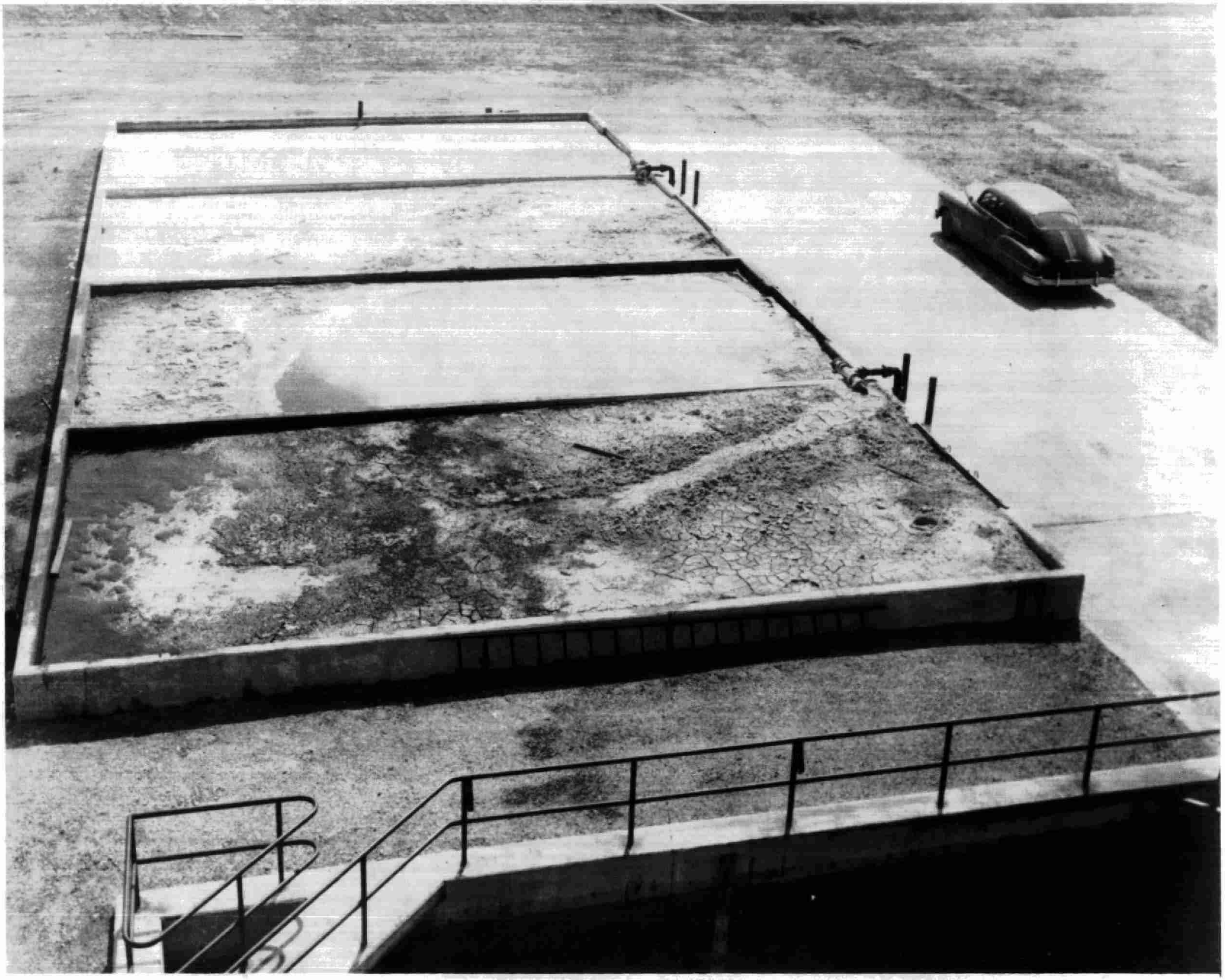


FIGURE 15, APPEARANCE OF SLUDGE IN PROPERLY ENGINEERED DRYING BEDS

NIAGARA DU PONT PLANT

- by -

George R. Amery

Du Pont Company
Niagara Falls, N. Y.

INTRODUCTION

At Du Pont--pollution abatement is paramount in the efficient and proper operation of a process. The pollution control group at the Niagara Falls Plant reports directly to top plant management as a staff function. It is charged with the maintenance of quality and purity of effluents discharged to the river, removing undesirable constituents from wastes discharged to the municipal sewage treatment plant as well as maintaining adequate sampling, analyses and records of all plant outfalls.

The management at Du Pont plants are keenly aware of their obligation to the community and responsibilities to operate their plants with concern for the rights of their neighbours. Pollution abatement and conforming to the standards of purity established by the Water Pollution Control Boards for the streams on which our plants are located is not only a matter of neighbourliness but also an obligation as a corporate citizen of the community.

Among the important corollaries of the Du Pont pollution abatement policy is the following statement: "Development of a new process is not considered complete until it includes a satisfactory method for disposal or treatment of wastes".

Products of the Niagara Plant are sodium, electroplating salts, peroxygen compounds, chlorinated hydrocarbons, vinyl polymers and nylon intermediates. Sewage wastes are discharged to the Niagara River, either directly or through the municipal sewer system. The Niagara is a large stream with a relatively constant rate of flow of 200,000 cfs. As a result, in spite of high concentrations of industry in the area, the oxygen content of the river has never been seriously impaired.

Periodic and highly objectionable instances of contamination affecting taste and odor of public water supplies have occurred between the Buffalo area and Niagara Falls. This led to a study of pollution conditions along the entire run of the river by The International Joint Commission. This Commission made up of representatives of the United States and Canada, began its investigation during 1948 with a request that all industries in the area supply information on the amount and character of their sewage.

The effluents from all plants, along the Niagara River fall under the general supervision of The International Joint Commission. Pollution abatement activities for New York citizens, however, and the enforcement of rules and regulations are controlled by The New York State Water Pollution Control Board. Toward that end, the Board has developed a comprehensive plan for pollution abatement involving some 102 communities and industrial plants in the drainage basin of the Niagara River and the east end of Lake Erie.

One result of these investigations has been to focus attention on the inability of the Niagara Falls Municipal sewage disposal system to handle the large volume now received from domestic and industrial sources. The sewage plant is designed to handle 50 M.G.D. total load and has been taxed at times with hydraulic loadings up to 88 M.G.D.

THE WATER POLLUTION ABATEMENT PLAN FOR THE NIAGARA PLANT

It was obvious to Niagara Plant management that additional information on plant effluents was necessary to fulfill the requirements of company-wide policy on pollution abatement. A group of engineers was assigned to the task of surveying and analyzing all outfall streams and an abatement program was developed on the premise of abolition, wherever possible, of all undesirable features from plant outfall streams. Considerable future planning was involved and included waste treatment standards to be met in the design and construction of proposed processes at this plant site. It is important to note that this work is done at a top management level as a staff function, rather than a line organization responsibility under production or plant engineering; the results are, therefore, more objective than they otherwise may be.

The comprehensive abatement plan developed by the Water Pollution Control Board for all contributors to Niagara River pollution included items for the Niagara Plant, the main features of which are as follows: (1) achieve maximum elimination of cooling waters from municipal sewers to reduce the load on the sewage treatment works. (2) study the receiving stream and plant effluents using bio-assays to determine the toxic effects of plant wastes on fish life. (3) study the various constituents in the industrial waste effluents which interfere with normal operation of the sewage treatment works. (4) establish plans for effluent sampling, maintain operating records and make periodic reports to the Water Pollution Control Board.

ELIMINATION OF COOLING WATER FROM MUNICIPAL SEWERS

As an example of one study, the Water Pollution Control group made a complete water balance around the plant; all incoming and outfall water was measured and analyzed. Flow measurements of incoming water showed that 48 M.G.D. of water was pumped to the processes of the Niagara Plant. A gurley flowmeter with auxiliary equipment was used on both storm sewer and municipal sewer outfalls. The survey showed that 41 M.G.D. flowed directly to the river and 7 M.G.D. was flowing to the municipal sewers. Investigation on this 7 M.G.D. involved an extensive study of all outfall lines from many processes. Some lines could be traced directly while others had to be traced with the use of fluorescein dye. In the course of the investigation it became apparent that as processes grew from semi-works operation to full scale production, some cooling water was piped to municipal sewer outfalls without the knowledge that the treatment plant was being hydraulically overloaded.

Piping changes to storm sewers reduced the load by 2 M.G.D. the first year. Projects are now under way to reduce the load by an additional 2.7 M.G.D. One of these projects will involve the reuse of some 1,000 G.P.M. of water used for cooling electrical transformers at one of our substations. The temperature rise shows that there remains substantial heat absorbing capacity in the water now discharged to the sanitary sewers. By repumping the water to a head tank in the area for reuse in the processes, we not only reduce the hydraulic load on the municipal sewers but also gain cooling water capacity in an area where it is needed. The spent water from the processes is discharged directly to the river.

SURVEY OF PLANT OUTFALLS

An extensive monitoring system has been set up involving sampling and analyzing 17 stations including outfalls to the municipal sewage system, storm sewer outfalls to the Niagara River and two incoming raw water pumping stations. Representative samples taken daily from each station were analyzed for all constituents in accordance with standards established by the A.P.H.A. and A.W.W.A. This program required three control analysts and two samplers full time. As results from the monitoring system were tabulated and compared with analyses of the receiving waters, it became obvious that many outfall streams were comparable to the receiving waters. The sampling program has thus been reduced in these cases with some composite analyses being run weekly and monthly on a monitoring basis, while the outfalls to the municipal sewer system continue to be analyzed daily.

During the course of this study, a material considered toxic was detected in excess of the concentrations indicated in the rules and classifications and standards of quality and purity for water of New York State. The startling fact was that the contamination was being discharged from processes having no connection with it. Subsequent investigation, including taking traverse samples of the river upstream from the plant, disclosed that a solid waste pit containing this material was responsible and through leaching action the material had found its way to the raw water pumping station intake and was being pumped through the condensers of various processes. The wastes in the pit were neutralized, the waste pit was abandoned and filled in and the ground water below this section of the plant was decontaminated by actually sinking wells so the water could be treated.

NIAGARA PLANT PROCESS WASTES

The Niagara Plant has always faced keen competition in the chemical industry in all of its processes. This has helped our pollution problem because as technical personnel strive to improve yields and reduce costs, the material going down the sewer has come under continuous technological scrutiny. In one case of low yields involving a considerable area of the plant, continuous sampling stations were used on the outfall water from every major piece of equipment. Each stream was analyzed for traces of product, by-product or raw material leaving the process. Such techniques result in process improvements and changes which recover valuable products as well as reduce sewer contamination.

In one of our processes, even after extensive refuse of wastes, it was found that a toxic waste in excess of standards was being discharged to the sewer. A complete development program was carried out in a laboratory and pilot plant scale to treat the waste with chlorine and alkali. The method proved to be completely successful and preliminary engineering drawings and flow sheets were made for application on a plant-wide scale. A cost estimate showed the cost to be relatively high, but in line with company policy, it was felt that it would receive approval.

By this time the analyses of all plant waste streams had been determined in detail. It was known that the pH of the outfall was in the proper range to accomplish treatment and two waste streams from other processes carried necessary treatment components. By combining these wastes and analyzing downstream, it was found that the toxic waste was reduced to an acceptable value. One important feature was that the pollution was abated immediately without the delay for design and construction of a treatment plant. Plans previously developed are being held in abeyance pending continued good analytical results.

Another constituent in our municipal sewer outfalls requiring study and a program for correction has been settleable solids. The outfall of the Niagara Falls Sewage Disposal Plant contains settleable solids which are attributed in part to industrial sources. This problem is far less complex to the pollution control engineer than chemical waste treatment. By installing facilities for handling insolubles inherent with rock salt which must be refined for our sodium process, these solids, formerly going to the municipal sewers are collected and disposed of at a solid waste disposal site. Two new boiler installations have included fly ash collecting and handling equipment to conform with both air and water pollution control legislation.

SOLID WASTE DISPOSAL

Disposal sites for such solid wastes as fly ash, brine mud removed from municipal sewers, incinerator ash and miscellaneous rubble, continue to be a problem for the Niagara Plant. Numerous geological surveys, soil permeability and rock coring tests have revealed sites in Western New York particularly adaptable to receiving our wastes; however, in many instances these areas have restrictions against industrial waste disposal. It is believed that continued effort will eventually result in the right combination of geological features, transportation arrangements and community approval to effect an adequate solid waste disposal site.

One solid waste disposal site investigation might be mentioned here. Approximately 350 acres of relatively poor land was optioned for a disposal site because it seemed to have several advantages:

(1) it was isolated from communities and adjacent farms,
(2) it was situated between two railroads,
(3) geological maps from the state historical society indicated that the sub-surface structure was impervious to the flow of leached wastes from the site.

A complete soil investigation was made as well as core borings and pressure tests to a depth of 50 feet in rock at four locations on the property. All tests showed this to be an ideal solid waste disposal site; a site which would assure no nuisance to our neighbours and one which would carry minimum responsibilities for the company in years to come. This indicates the type of investigation considered necessary in the development of a solid waste disposal site. Ground water also comes under the jurisdiction of The Water Pollution Control Board and it is important to the company not only to maintain the purity of underground waters but also to maintain a high level of public relations in these areas.

BIO-ASSAYS

As noted above, the pollution abatement plan for the Niagara Plant was to include "Bio-Assays". The first impression one gets of this control method might lead to the conclusion that running bio-assays is beyond the field of a professional engineer working on pollution abatement. Furthermore, the control laboratory of the average chemical plant is hardly a biological laboratory. The Du Pont Company, as a general service has bio-assays run by qualified laboratories specializing in this type of service. Noting that the plant had (17) major outfall streams and many more side stream feeds, it seemed totally impractical to enter a program utilizing this service as a day-by-day control tool.

As the water pollution abatement program has proceeded and more information on our industrial wastes has been cataloged, it had become apparent that rough bio-assays, using fish as a control medium, were necessary for complete information on plant wastes. As another step toward complete waste control, rough bio-assays are now run on the plant as part of the abatement program. A biological background is not required to determine whether or not waste streams are highly toxic to fish; and the possibilities of this control method are almost beyond imagination. There are many complex organic chemical wastes which could be highly toxic and yet not show up on the normal tests run while examining sewage and industrial wastes. On the other hand, some toxic wastes exceeding the limit established for streams may not kill fish, due to antagonism or dilution. It would seem that an actual test of toxic wastes with fish would supply necessary technical information as well as excellent data for public relations.

With these motivating premises, a small laboratory for running industrial bio-assays has been set up in a pump house on the Niagara River. The article entitled "Industrial Bio-Assays" by Henderson and Tarzwell appearing in "Sewage and Industrial Wastes", September 1957, has been used as a guide. Fish from the receiving stream, the Niagara River, are used as test animals. These include carp, perch and silver bass weighing 2 to 3 grams each. A four to five gallon sample of the plant effluent to be tested is procured in a manner to be as representative as possible. Using two liter test solutions composed of the receiving stream water and various percentages of the waste stream, two fish are placed in each solution. In a 24-hour period the median tolerance limit can be bracketed. When the toxic range is known, larger test solutions involving ten liters are made up and ten fish are used in each test for 48 hours with a check at the end of 24 hours.

The median tolerance limit is defined as the per cent concentration of the waste in the receiving water where half of the fish live and half die in 48 hours. For our tests at the present time, a median tolerance limit of 10% of the water in the receiving stream water is considered satisfactory although some tests are run in 100% waste water. These effluents are thereby proven to be equal without dilution to the receiving stream. The allowable tolerance limits will vary, of course, with the amount of dilution the receiving stream provides.

The details of running bio-assays are not at all complex. Test fish are obtained from the river, in our case from traveleing screens at the pumping station. Up to two hundred fish are kept in an aereated 5 gallon gas bottle. The water is changed and fish are fed three times a week. The test samples, diluting water from the river and aquarium, are kept at nearly constant temperature since temperature changes of more than 3°C. may kill fish. A limited number of control analyses are made on the test solution during the 48 hour test period. These include pH, dissolved oxygen, alkalinity, hardness and any special tests as determined by the characteristics of the waste. The purpose is to make sure nothing other than the waste itself influendes the health of the fish. This is the reason, for instance, that chlorinated tap water is not used as diluting water.

Looking to n the future, bio-assays can be run with comparative ease on waste products resulting from laboratory explorations of new processes. This will give ample time to work out treatment methods and these can be included in the process design and construction with full confidence that the plant will not be a nuisance to its neighbours.

We have confidence that the continued co-operation of the Niagara Plant with local authorities and state water pollution comtrol people will be beneficial to the plant as well as the people of New York State by keeping the quality of the Niagara River up to the proper standards for its best usage.

THE OWRC'S STREAMLINED APPROACH TO POLLUTION AND INDUSTRIAL WASTE PROBLEMS

- by -

Mr. A. M. Snider, Chairman

Ontario Water Resources Commission
Waterloo, Ontario

There should be no need of telling you how pleased I am to have this opportunity of addressing you this evening -- because many of you already know I always consider it a privilege indeed to be in the company of people interested in anti-pollution programs. In my visit to this industrial waste conference I have followed the program with interest and much satisfaction.

The satisfaction springs from the fact that your discussions show that industry, for the most part, is trying to help itself where the problem of industrial wastes is concerned -- it is doing its utmost to co-operate with authorities charged with making our water courses safe for whatever use we humans wish to put them.

You, gentlemen, representatives of various industries and municipal administrations -- all with challenging wastes disposal problems -- are to be congratualed for the part you are playing in this gigantic fight to cleanse our water resources. As far as Ontario is concerned, the Commission has received excellent co-operation from the great bulk of industrial firms and municipalities. They are working with us and we are working with them -- the only practical manner in which such a complex problem can be met.

These industrial waste conferences, sponsored by the Ontario Water Resources Commission through its Water and Pollution Advisory Committee are a forward step in the program of pollution abatement. They bring together those who are specialists in this field in an attempt to solve many problems and exchange information on how some are meeting certain situations which, perhaps, have proven baffling to others.

They provide, above all, opportunities for co-operation between industry and those who are concerned directly with pollution control. It is my belief that such gatherings can not help but prove of great assistance to all in the advancement of sanitary science.

Some of you may not be entirely familiar with what the OWRC's Water and Pollution Advisory Committee is doing and how it functions in conjunction with the Commission's overall activities. This committee has been functioning for a number of years, first as the Pollution Control Board and now under the Commission. It is a technical body interested primarily in those complex problems which arise in the industrial waste field. The value of a technical group of this type to the Commission will be apparent to all, because the many problems which are continually arising in the field of industrial wastes call for the closest study. It is imperative that such wastes be disposed of in a manner which will not impair the quality of surface waters into which they are discharged.

Stream pollution today is recognized as something which must be approached from many different angles. It is not sufficient to consider pollution only in the light of its effect on public health, but also anything which interferes with any of the many uses of surface waters. There must be no interference with fish life, recreation, agricultural use, domestic use, industrial use or other uses to which water may be put.

Pollution can arise from many sources in addition to domestic sewage and it is essential that any approach to pollution abatement must be through control of these various sources. For this reason the Water and Pollution Committee is composed of representatives of various Ontario Government departments as well as the OWRC. Departments represented are Lands and Forests, Mines, Agriculture, Municipal Affairs, and Planning and Development.

This Committee must play an important role in pollution abatement. It is expected to keep the Commission advised on special technical problems and to bring in recommendations from time to time concerning methods of handling these problems.

Today, as never before in the history of Ontario, there is need for efficient handling of industrial wastes. These wastes come from many different processes and their composition varies tremendously. It logically follows, therefore, that such wastes cannot be treated as easily or in such a uniform manner as domestic sewage. This means that there is great scope for the Committee working in conjunction with the Water Resources Commission. As for the Commission, it is our intention to ensure that laboratory and other facilities are made available to the Committee to enable it to work closely with other groups concerned with research into and the eventual solution of these various industrial waste problems.

There is no need of telling you the Ontario Water Resources Commission is in the forefront of the fight against pollution in this Province. The Commission was set up to do a number of things but basically these boil down to the protection and proper distribution of Ontario's water resources -- and this includes the elimination of pollution caused by sanitary and industrial wastes. We believe we have a good streamlined approach to the problem.

Both water supplies and wastes disposal should be linked in any program designed to provide water in sufficient supply and of good quality to meet the needs of all the people. The Ontario Water Resources Commission is thoroughly appreciative of the needs of Ontario and of the practical problems to be overcome in meeting those needs.

It has definite objectives in mind -- objectives designed to assist in the solving of difficulties in various parts of the Province arising from the need for water supplies and the disposal of sanitary and industrial wastes. The Commission's objectives are twofold in nature. One is to ensure maintenance of public water supplies in a safe condition for domestic consumption and other uses -- and this, naturally, includes the proper treatment of sanitary and other wastes before they are discharged into water courses. The second objective is to make it possible for municipalities to finance modern water and sewage works for any area where required.

The needs of Ontario for water and sewage works are great. It is estimated that in the next 20 years these works will require an expenditure of 2.4 billion dollars. This Province is growing rapidly. Industry is expanding. More water will be needed and more wastes of all kinds must be disposed of. It is imperative that these essential utilities be planned in advance so that the growth and welfare of the Province will not be hindered through lack of these necessities. We also must realize that the need for water and sewage works will be a never-ending problem as the Province grows.

To reach its objectives the Commission has been given certain powers by The Ontario Water Resources Commission Act, 1957 -- which was tightened with amendments at the 1958 session of the legislature. For instance, Section 16 of the Act reads as follows:

"(1) Notwithstanding any other Act, it is the function of the Commission and it has powers,

"(a) to control and regulate the collection, production, treatment, storage, transmission, distribution and use of water for public purposes and to make orders with respect thereto;

"(b) to construct, acquire, provide, operate and maintain water works and to develop and make available supplies of water to municipalities and persons;

"(c) to construct, acquire, provide, operate and maintain sewage works and to receive, test and dispose of sewage delivered by municipalities and persons;

"(d) to make agreements with any one or more municipalities or persons with respect to a supply of water or the reception, treatment and disposal of sewage;

"(e) to conduct research programs and to prepare statistics for its purposes; and

"(f) to perform such other functions or discharge such other duties as may be assigned to it from time to time by the Lieutenant-Governor in Council.

"(2) Every person who contravenes or fails to comply with any order made under clause (a) of subsection 1 is guilty of an offence and on summary conviction is liable to a fine of not more than $100 for every day or part thereof during which such contravention or failure continues."

Supervision over all waters is given the Commission by Section 26 sub-sections (1) and (1a) of the Act which reads:

"(1) The Commission has the supervision of all surface waters and ground waters in Ontario used as a source of water supply.

"(1a) The Commission may examine any surface waters or ground waters in Ontario from time to time to determine what, if any, pollution exists and the causes thereof."

In regard to sewage works, the Act says in Section 37:

> "Sewage works shall at all times be maintained, kept in repair and operated in such manner and with such facilities as may be directed from time to time by the Commission."

Section 27 of the Act contains an instance of legislative "teeth" to help the Commission in its anti-pollution crusade. It reads:

> "(1) Every municipality or person that discharges or deposits any material of any kind into or in any well, lake, river, pond, spring, stream, reservoir or other water or water course that may impair the quality of the water of such well, lake, river, pond, spring, stream, reservoir or other water or water course is liable to a penalty of not more than $1,000 or to imprisonment for a term of not more than one year, or to both."

Further, Section 38 (2) of the Act provides that every municipality which fails to do every act and thing in its power to implement a report made to it by the Commission in connection with water works or sewage works is guilty of an offence and on summary conviction is liable to a penalty of $500 for every day upon which such default continues after receipt of the report.

In connection with pollution abatement, the Commission will co-operate with any individual, municipality or industry with a problem. Each will be given an opportunity to work with the authorities whose aim is an abundant and clean water supply for the people of Ontario. However, if an offender fails to co-operate in a manner suggested by the Commission, it is the intention of the Commission to prosecute in court to attain its objectives.

However, we hope there will be little need for legal action -- for recourse to the courts. We don't want to have to wave the big stick but we will if we have to. As I stated a few minutes ago we must make sure that all of Ontario's water resources are fit for human use. This will take time but I am sure it can be worked out through the medium of understanding, common sense and a spirit of co-operation.

As far as industrial wastes are concerned we realize that industry for the most part is doing a progressive job by itself right now. We also realize that some industries are finding some of their waste disposal problems almost insurmountable. Let me say here and now that the Ontario Water Resources Commission is not out to strangle economic life -- it will gladly co-operate with these industries in an effort to find a solution to their problems. OWRC personnel are available always to advise and help in regard to such problems.

The same program for pollution abatement applies to municipalities. Industrial wastes and domestic sewage must be dealt with at the same time. The Commission recognizes the difficulties which confront municipalities in the treatment of sewage, particularly in respect to cost. These problems must be solved so that the water courses of the Province can be protected.

Many municipalities are proceeding. Others must expect the Commission to insist that action be taken. Those municipalities which have not received these requests as yet from the Commission may expect them soon.

Water purification for domestic use must be provided and maintained under all circumstances. The Commission must insist on adequate safeguards to protect the water consumers. Careful supervision is being given this by the highly trained personnel of the Commission.

Our laboratory and research facilities are available to industry and to municipalities -- and these facilities will be increased greatly when our new laboratory, now under construction in northwest Metropolitan Toronto, is opened next year. It will be modern in every conceivable way.

Our personnel also are available to advise municipalities with water and sewage disposal problems. To alleviate water shortages and help banish pollution through proper disposal of sanitary wastes the Cpmmission has a program designed to aid in the construction and financing of water and sewage works for any municipality or for any area where there is a need.

To begin with, municipalities may plan, build and finance such works on their own providing their plans have been approved by the Commission. On the other hand the Commission is prepared to take over the responsibility of such installations, with the municipalities concerned repaying the Commission on a long-term basis. Such municipalities benefit in numerous ways -- planning, construction, financing and operation, all of which is undertaken by the OWRC. The rate of interest paid by these municipalities is not fixed, but is based on the Commission's total borrowings each year.

This mass borrowing by a Commission with the backing of the Ontario Government tends to obtain lower interest rates for the benefit of municipalities involved in OWRC projects.

It should be noted that it is possible for two or more municipalities to enter into a combined agreement with the Commission for the construction of integrated water or sewage works. This, for example, is an economical way for inland cities, towns and villages to obtain water from distant sources via pipeline, or for adjacent municipalities to make use of a joint sewage treatment plant.

Since we actively started on such projects in the spring of 1957, we have built, are building or have undertaken to build approximately twenty million dollars worth of works -- more than thirteen million dollars sewage and more than six million dollars water.

Three water works projects are in operation at Port Perry, Sunderland and Havelock, while a new sewage treatment plant is in partial operation at Stratford. It will be officially opened in mid-summer. Largest project we have undertaken so far is construction of an integrated water scheme in Essex County which involves a pipeline from Lake Erie to serve Leamington and the Town of Essex and the intervening townships. This is a three million dollar proposition.

Other sewage projects are at North Bay, with two adjoining townships also involved, Trenton, Tillsonburg, Brampton, Brantford, Toronto Township, Bancroft, Port Arthur, Coniston, Frankford, Richmond Hill, Korah Township and Streetsville.

Other water projects are at Alfred, Winchester, Dundas, Markham Township, Essex, Bancroft, Dresden, Frankford, Harrow and Richmond Hill.

Negotiations leading to probable agreements also are being carried on with numerous other municipalities including my hometown of Waterloo, neighboring Kitchener, Sault Ste. Marie, Brighton, Woodbridge, Burlington, Tay Township, Waterford, Bolton, Cookstown, Fergus, Mitchell, London Township, Wallaceburg, Collingwood, Newmarket, Bradford, Bertie Township, Huntsville, Orangeville, Armstrong, Marmora, Kenora, Paris, Dunnville, Georgetown and Markham Village.

That should keep us busy for a time, but in addition we have a stream survey staff which is engaged in checking on water needs and on pollution in various water courses on a county basis. Right now we are concentrating on counties in watersheds where water problems appear most acute -- and this includes most of southwestern Ontario.

All in all, the Ontario Water Resources Commission is faced with a job of great magnitude. However, we feel we can accomplish our objectives as long as we have the help and co-operation of all interested municipalities, industrial firms, conservation authorities and individual citizens. We are grateful for the co-operation we have received thus far. It made our progress that much easier when the going was toughest -- in our first formative years.

We are proud of the fact that in 14 months our staff has increased from two persons to well over 100 and that in that short time we arranged water and sewage projects valued at close to twenty millions. Thank you.

INDUSTRIAL WASTE CONTROL AT AN ORGANIC CHEMICAL PLANT

- by -

R. E. Mills, M.C.I.C.

Naugatuck Chemicals Division of
Dominion Rubber Company Ltd.

Naugatuck Chemicals Division of Dominion Rubber Co. Ltd., is involved in the manufacture of a wide variety of rubber, agricultural, industrial chemicals and plastics and has within itself many potential sources of air and water pollution.

The plant is located in a small town in central Ontario in the midst of a fine agricultural district, and as a result all wastes must be carefully controlled to maintain good relations in this community.

The organization and handling of the control problems is most important and the methods used depend to a large measure upon the type and size of chemical plant concerned.

This paper is divided into two main groups; I Air borne wastes control and II Waste water control problems.

I - AIR BORNE WASTES CONTROL

It seems fitting and proper to examine the problem of air borne wastes from the view point of a human being. An average man breathes 22,000 times each day taking in 35 lbs. of air. (1) Air is the main link to life and far exceeds the consumption of food and water. Therefore, the development of an air borne wastes control program produces an atmosphere in which it is pleasant to work and is a powerful aid to the control of industrial hygiene with which we are all concerned.

Management at Naugatuck has always maintained a conscientious concern in trying to keep the atmosphere in and around the plant free from objectionable odors, vapours and dusts, and has for many years been carrying on a persistent and active program of air borne wastes control.

Many of the installations used at our plant to control the discharge of air borne wastes were discussed in a previous paper (2) Recently, the operation of some of these has been further evaluated and are again discussed here.

CONTROL OF DUSTS AND FUMES FROM THE 2,4-D PROCESS

A large fume absorption system Figure 1, handling 4000 - 4500 cfm of air was installed about 1951, to control the dusts and fumes from the 2,4-dichlorophenoxy-acetic acid (2,4-D) process. The scrubber (3) is a Schneible multi-wash dust Collector and consists of a 16 ft. high x 4 ft. diameter vertically placed cylindrical tower. Dusts and fumes enter the tower tangentically through ducts into a wet cyclone where the heavier particles separate. The absorbing solution is recirculated from a holding tank below, entering the tower above its top impingement place and in its downward motion washes the up coming air. Dusts and fumes are effectively removed by this device. An exhaust fan on the clean air outlet draws the air through the scrubber. The absorbing solution is recirculated until spent, then renewed; this requires regular testing and is part of the process operation. The electrical connection on the exhaust fan motor and recirculating pump motor are interlocked in such a manner that the pump must be going before the fan starts. This prevents ejection of unscrubbed air. The outlet air from this installation is continuously sampled and the daily quantity of 2,4-D emitted is of a very low magnitude. The efficiency of the scrubber was measured at over 95%.

The hood is considered the most important or critical part of any exhaust system. It is the function of the hood to enclose the source of contamination as completely as possible and/or to create an air flow pattern at the point or in the area of contaminant escape of such a velocity and direction as to capture the grossly contaminated air and convey it into the local exhaust system. If this is not achieved, the fume absorption system cannot be expected to properly do what is expected of it. The minimum air, or control velocity for the capture of fumes and vapours released into moderately quiet air is 100 - 200 ft./min. (4) Also the depth of the control air stream plays a most important part in the capture of the contaminated air. The capturing power of an air stream into an exhaust hood is a function of the product of the velocity and the distance through which it acts, not of the velocity alone. Figure 2 shows the depth of the control air stream of several of the more important hoods in this system. Recent evaluations were made in this part of the system in an effort to further improve operation.

Air sampling carried out at various locations throughout the building indicated an average 2,4-D concentration of 0.1 gm per 1000 cu. ft. of air. Air flow measurements were also made at open doors and windows and found to be much higher than expected. This investigation indicated that considerably more of the dusts and vapours were escaping the hoods and getting to the atmosphere than were emitted from the clean air side of the scrubber.

As a result of this survey the filter hood was modified, figure 3, and one particularly dusty operation was completely enclosed and coupled by a duct to the fume absorption system. Neither of these modifications interfered appreciably with production operations. Operating instructions were modified slightly to require man-hole covers to be kept in place except when actually used. The very short period of time in which most of the man-holes must be open does not justify any modification of the hoods located above them. As a result of these modifications, costing less then $300. the 2,4-D content of the air in the building dropped from 0.1 gm to less than 0.0001 gm/1000 cu. ft. of air.

OXIDES OF NITROGEN

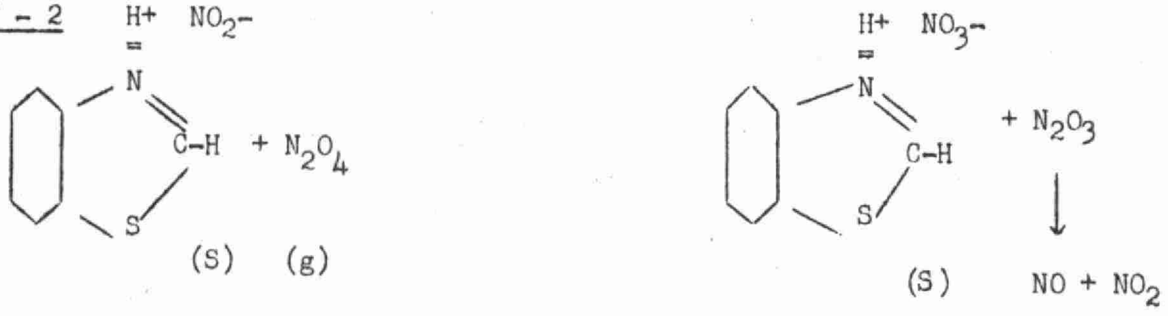
Oxides of nitrogen are present in the effluent gases from one of our processes involving the oxidation of mercaptobenzothiazole with sodium nitrite. A specially constructed rachig ring packed ceramic tower was installed about 1948 to carry the nitrous oxide fumes from the process vessels to the tower. A recirculating caustic solution is used to scrub the effluent gases forming sodium nitrite and nitrate which is subsequently returned to the process.

A recent investigation of this fume absorption system indicated two conditions of operation which lessen the efficiency of the system as a whole.

The first condition is one in which blocking occurs in the ducts before the absorber and also after the absorber between the absorber and the suction fan indicating that the caustic absorbing solution does not remove the offending material. If the operator is not alert, fumes could escape into the building before he can unblock the ducts with a water spray. The yellow-brown material causing the difficulty was identified as benzothiazole nitrate, a salt. Benzothiazole itself is a base, and is a side reaction product of the production of mercaptobenzothiazole. This compound has a mercaptan like odour of great staying power even in a brisk wind. It was concluded that the benzothiazole was partly distilled out and partly transported by the ascending nitric oxides to the cool ducts where it condensed to the liquid state again and became nitrated to form the nitrate salt. A possible formation reaction of the solid is as follows:

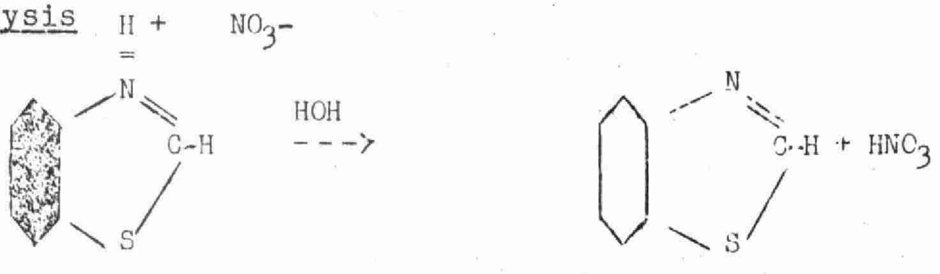
REACTION - 1 Vapour phase reaction

REACTION - 2



The ease with which the ducts can be unblocked with water is due to the hydrolysis of the nitrate salt as follows:

Hydrolysis



After steam stripping a sample of sodium mercaptobenzothiazole 2% pure benzothiazole separated from the steam distillate and 3% of an amber coloured oil was extracted from the distillate itself. Infra red analysis indicated that the oil was benzothiazole contaminated with a trace of aniline. Our Development Dep't., is currently investigating the feasibility of removing the benzothiazole from the aqueous sodium mercaptobenzothiazole by steam stripping. The successful removal of this material would eliminate blocking of the ducts of the fume absorption system, produce a product of improved colour and odour, produce benzothiazole of possible sales value, and remove the cause of a very offensive odour eminating from this process since the benzothiazole will pass through the caustic absorber to the atmosphere (5).

The second condition of operation which lessens the efficiency of the system is the lack of sufficient air velocity at the open man holes of the same process vessels. As a result, fumes are not retained within the vessels when the man holes are open even when the ducts are completely free of any solid material as previously discussed.

When either man hole cover is open the calculated air velocity at the face of the opening drops to 57 Ft./min., figure 4. It will be noted also that with the present installation, the direction of air movement is from the vessel up through the man hole extension through small holes on the periphery of the inside of the extension to the duct. It is quite apparent that most of the fumes moving upwards will pass right out into the building when the man hole is open since the small holes located within a few inches of the man-hole face cannot capture the fumes across the entire 1.77 sq. ft. of man-hole.

To prevent the escape of fumes from these vessels during certain phases of the production operation, in which the man holes must be open, the equipment modifications shown on Fig. 5 were recommended. As shown, the man-hole extensions were removed, the area was reduced to one-half the original area by cutting and hinging the cover, the ducts were connected into the top of the vessels and spray jets were installed in the ducts. These modifications increased the air velocity through the half man-hole to 114 ft./min. and changed the direction of air movement so that it now flows down through the man-hole to the duct rather than upwards.

To further improve the atmospheric conditions within this building during the steaming out of the tar settlers, Fig. 6, the vents of the 3 vessels were coupled together and connected through a water jacketed line to a 45 gal. drum on the ground floor of the building. A vent line was installed from the drum back to the roof. A rupture disc was incorporated in the system as a safety precaution. Previously steaming out created a condition where the steam poured from the vessels into the pent house of the building and rolled down into the building itself.

During another phase of the operation of this process, sulfide waters were discharged to an outside sump through a pipe located in an open floor drain. Outside air currents carried the odour back into the building until a 3" down pipe was placed on the end of the drain and run subsurface in the sump, Fig. 7. While a simple device, this installation also greatly improved the working conditions in this building.

In the making of mercaptobenzothiazole, a mixture of hydrogen sulfide and carbon disulfide is evolved. These sulfides can be the source of very objectionable odours during periods of unfavourable winds due to their low odours thresholds. Investigations are presently being carried out to determine the most satisfactory method of eliminating these odours. It is hoped that these low sulfide effluents can be burned to sulfur dioxide before liberation to the atmosphere. The strong hydrogen sulfide gas evolved from this process is presently burned in an incinerator at the base of a tall stack (2) and it may be possible to couple into this system.

CAR SPOTTING

Some time ago several of our employees drew our attention to the fact that spots appearing on their cars may be coming from our plant. An investigation at the time did not prove or disprove their suspicions. In an attempt to obtain some reliable information of actual happenings, small white painted plates, 4" x 8", were made and placed along the roofs of building adjacent to the parking lots. The plates were placed at a 45° angle to the horizontal. These plates are examined once a week and to date, no spots have been noted.

ODOUR CONTROL PROGRAM

Our odour control program has been materially aided by the recent installation of an anemograph (automatic wind speed and direction recording equipment). This instrument assists in locating the sources of mal-odours thus avoiding the expenditure of time and money on suspected sources that are actually not the chief offenders. It also provides a record which indicates where contaminants from a given source have flowed, are flowing, or will flow. The instrument provides a record of the daily and seasonal frequency of various winds around which certain odourous production operations may be scheduled. It also provides some self defence against complaints that do not originate from our operation.

INCINERATION OF ORGANIC WASTES

At present our organic wastes are disposed of by burying some and burning others. These organic wastes include paper, cardboard and packing material, tars and still residues, filter cake, organic solvents, and carbon disulfide.

The present methods of disposal are crude and burning in an open pit can take place only during favourable atmospheric conditions when the dense clouds of black smoke are blown away from all residential areas.

The foremen repponsible for the burning have shown great skill in avoiding difficulties due to negligible wind velocity and/or a sudden change in wind direction. They have been aided by two wind cones located at opposite ends of the plant and by the anemograph previously mentioned.

The wind cones are also used by the plant operators to control odours when the wind is blowing from the plant toward the town. Frequently certain odorous operations are postponed until the wind again blows from a westerly direction.

II - WASTE WATER CONTROL PROBLEMS

Naugatuck Chemicals is located on the banks of the Canagagigue Creek which empties into the Grand River. For this reason the condition of the creek is of vital importance.

First, the daily and mean monthly flow of this stream is recorded by a hydrometric station located one mile below the plant. The structure, including stilling well and gauge shelter, was installed by the company on the abutment of a bridge on a township road. The gauge, a 7 day recorder, was provided on a loan basis by the Water Resources Branch of the Dep't of Northern Affairs and National Resources, Ottawa. The gauging or calibration of the station is carried out by the Water Resources Branch while the weekly canging of charts on the recorder is done by the company. The records obtained are extremely valuable for predicting the flows expected for the entire year. These records also form the basis of our water control program.

Secondly the stream is inspected and sampled at regular intervals, the usual period being every month. Sam ples are taken upstream from the plant, at the plant, downstream from the plant, and at points 1 mile, and 3 miles below, and above and below the confluence of the river into which the stream empties, about 5 miles from the plant.

During the sampling the stream is inspected for algae and fish life which is a visual indication of the condition of the stream. The temperature is also recorded at the time of sampling. These water samples are compared for pH, chemical oxygen demand, dissolved oxygen, % oxygen saturation, and dissolved solids. As our water control program is further developed it is hoped that along with the chemical analysis more biological comparisons can be included. The latter is believed to be more indicative of a stream's actual condition.

BIO-OXIDATION

Several years ago Management of Naugatuck Chemicals decided to investigate the vio-oxidation process as a method of treating all plant waste waters. The ultimate aim of the study is to satisfactorily treat all of the waste streams shown on Table I. The successful treatment of these wastes would end the rather unsatisfactory disposal of the phenolic and 2,4-D wastes to closed pits, reduce the high cost of treating the 2,4-D waste water already discussed in previous papers, (2) (6), and reclaim the valuable land now used for lagooning the general plant wastes.

Accordingly, laboratory investigation began with a study of the phenolic and 2,4-D waste waters. This work is fully discussed in a previous paper (1). Based on encouraging laboratory results it was decided to advance to the pilot plant stage of the investigation.

The preliminary pilot plant studies were carried on in collaboration with the Dow Chemical Co. The pilot plant was a combined trickling filter and activated sludge unit employing Dowpac HCS as the filter media. A flow diagram of the unit is shown on Figure 8. During the first eight months operation of this unit, an attempt was made to treat only 2,4-D waste water. A complete discussion of this investigation is also given in a previous paper (6). In brief, however, the study proved that phenol (carbolic acid) can be successfully treated on this unit whereas dichlorophenol is only partially treated. The introduction of 2 chlorine atoms into the phenol molecule creates a compound, dichlorophenol, that inhibits the normal metabolic processes of the bacteria.

At the end of the 2,4-D production season in April 1957, the combined weak and strong phenol waste waters shown on Table I were treated by the unit. An average of 25% of the total flow of this waste was treated in the Dowpac trickling filter.

A removal of 99.9% phenol and 95.3% chemical oxygen demand (COD) was obtained. In August 1957, a rapid semi-quantative phenol determination (7) was adapted and carried out every 4 hours by the plant operators on the influent and effluent of the unit. As a result of this measure, the phenol loading to the unit was increased to its maximum limit at all times without fear of an upset due to overloading. Previously, the phenol loading had to be kept well below maximum to allow for the frequent surges of phenol that occured during normal operation.

During the month of October the trickling filter was operated at peak efficiency and 40% of the combined waste stream was treated. It was estimated that by increasing tower capacity by a factor of 4 or by adding 3 additional towers, the total volume of this waste water could be treated. This would result in a capital expenditure of approximately $3000. The estimated cost of treating the total combined phenol waste water in an expanded unit was calculated at $0.26 (summer operation) to $0.34 (winter operation) per pound of phenol destroyed. This cost includes labour, power, steam, laboratory services, depreciation and nutrients. An alternative method would be to treat these wastes by alkaline chlorination at a cost of $1.00

per lb. of phenol destroyed.

During the month of October additional sampling was carried out to determine separately the portion of phenol treated in the Dowpac tower and the portion treated in the activated sludge tank located under the tower. A summary of the data obtained for the month of October is shown on Table II. The study seems to indicate that this trickling filter design employing Dowpac HCS as the filter media is a satisfactory device for destroying phenol both from the standpoint of cost and operational efficiency.

In November 1957 further studies were carried on in a pilot plant Aero-accelator. The Aero-accelator, Figure 9, is a biological oxidation unit of the activated sludge type designed by Infilco Inc., Tucson, Arizona. The pilot plant is 62" in diameter and has an aeration volume of 17 cu. ft.

Infilco has been very generous not only in making this piece of equipment available to us, but also in the interest shown in the problem and the advice and direction offered throughout.

The following discussion of our pilot plant studies is very limited and will touch only on the main points determined to date since the study is as yet incomplete.

Operation began with the treatment of the strong phenol and aniline waste waters as an easily oxidizable waste suitable for building up the mixed liquor solids to a satisfactory level. When a satisfactory solids content was established, 2,4-D waste water was introduced into the feed mixture. This procedure was followed since the 2,4-D waste water had shown itself incapable of supporting a biological floc alone. Therefore, the only satisfactory means of treating this waste is by dilution with other easily oxidizable waste waters. The weak phenol waste stream was not included in the pilot plant studies due to handling difficulties.

The first successful period of operation included a 20 day period where the unit treated continuously a waste mixture of 2,4-D, aniline, and strong phenol waste waters in the ratio of 5.0: 2.1: 1.3 respectively. Operation was successful during this period and was expected to continue indefinitely due to the addition of trace amounts of cobalt, manganese, and ferrous salts and a 20 fold dilution of the waste with tap water.

On two previous occasions the unit had operated for about 14 days and then the sludge had broken down. The evaluation of this operational data indicated the lack of certain essential nutrients in the feed mixture. Hence the addition of the inorganic salts and the 20 day period of operation before it could be shown conclusively that the unit would continue to operate indefinitely.

During the second successful period of operation the unit treated continuously for 34 days a waste mixture of 2,4-D, aniline, and strong phenol waste water in the ratio of 10.0: 2.1: 1.3 respectively. The ratio selected is the flow rate of each waste in IGPM as it occurs in the plant. Operation was again successful during this period and was expected to continue indefinitely due to the daily addition of 5 gallons of settled sewage and a 20 fold dilution of the waste. The settled sewage replaced the inorganic salts since the latter evidently did not supply all of the essential nutrients necessary for bacterial growth. It has been thought that from the settled sewage the bacteria take the essential nutrients necessary for the metabolism of living things. In the case of bacteria, they are exactly the same essential nutrients or amine acids that are necessary for human life. Since the single cell organisms are unable to synthisize these materials themselves, they must then be present in their food supply.(8)

At present a waste mixture of general plant wastes, 2,4-D, and aniline waste waters in the ratio of 84: 10; 2.1 respectively is being investigated. The successful treatment of this mixture would complete the study and provide us with the data necessary for the design of a full scale waste treatment plant.

CONCLUSION

The foregoing is an outline of a few of the preventative and corrective measures that have been taken in the air and water wastes control program at Naugatuck Chemicals in Elmira.

A brief description of recent improvements in our 2,4-D and nitrous oxide fume absorption systems have been given.

A summary of the laboratory and pilot plant studies of the bio-oxidation process as a means of satisfadtory treating all plant waste streams has also been discussed. The successful completion of this study will provide data for the evaluation and possible design of a full scale waste water treatment plant.

BIBLIOGRAPHY

1. Magill, P.L., Holden, F.R., Ackley, C., "Air Pollution Handbook" McGraw - Hill Co. (1956)

2. Mills, R.E., "Industrial Waste Control at an Organic Chemical Plant", Third Ontario Industrial Waste Conference (1956)

3. Claude, B. Schneible Company, Detroit 32, Michigan - The Multi-Wash Senior Collector.

4. Brandt, A.D., "Industrial Health Engineering", John Wily & Sons, Inc., N.Y., (1947).

5. King, L., and Jenny R.J., Chemical Engineering 107 (Mar.1949)

6. Mills, R.E., "Progress Report on the Bio-Oxidation of Phenolic and 2,4-D Waste Waters." Forth Ontario Industrial Waste Conference (1957)

7. Fern, G.R.H., and Sheppard, A.A., "Report on Determination of Phenols in Petroleum Waste Waters by the Gibbs Method", Imperial Oil Limited, Sarnia Refinery.

8. Oginsky, E.L., Umbreit, W.W., "An Introduction to Bacterial Physiology," W.H. Freeman & Company, San Francisco (1954)

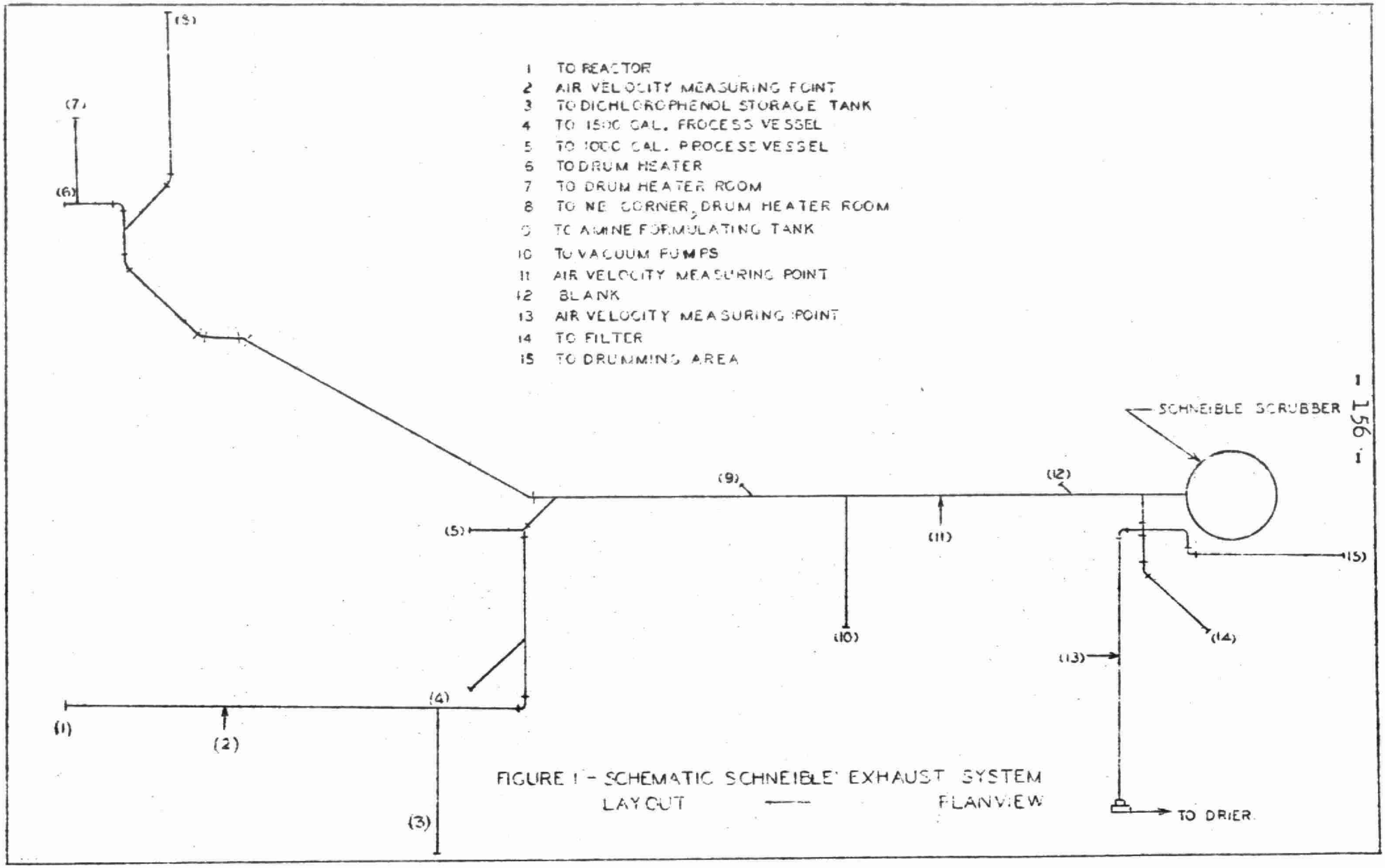


FIGURE 1 - SCHEMATIC SCHNEIBLE EXHAUST SYSTEM LAYOUT —— PLANVIEW

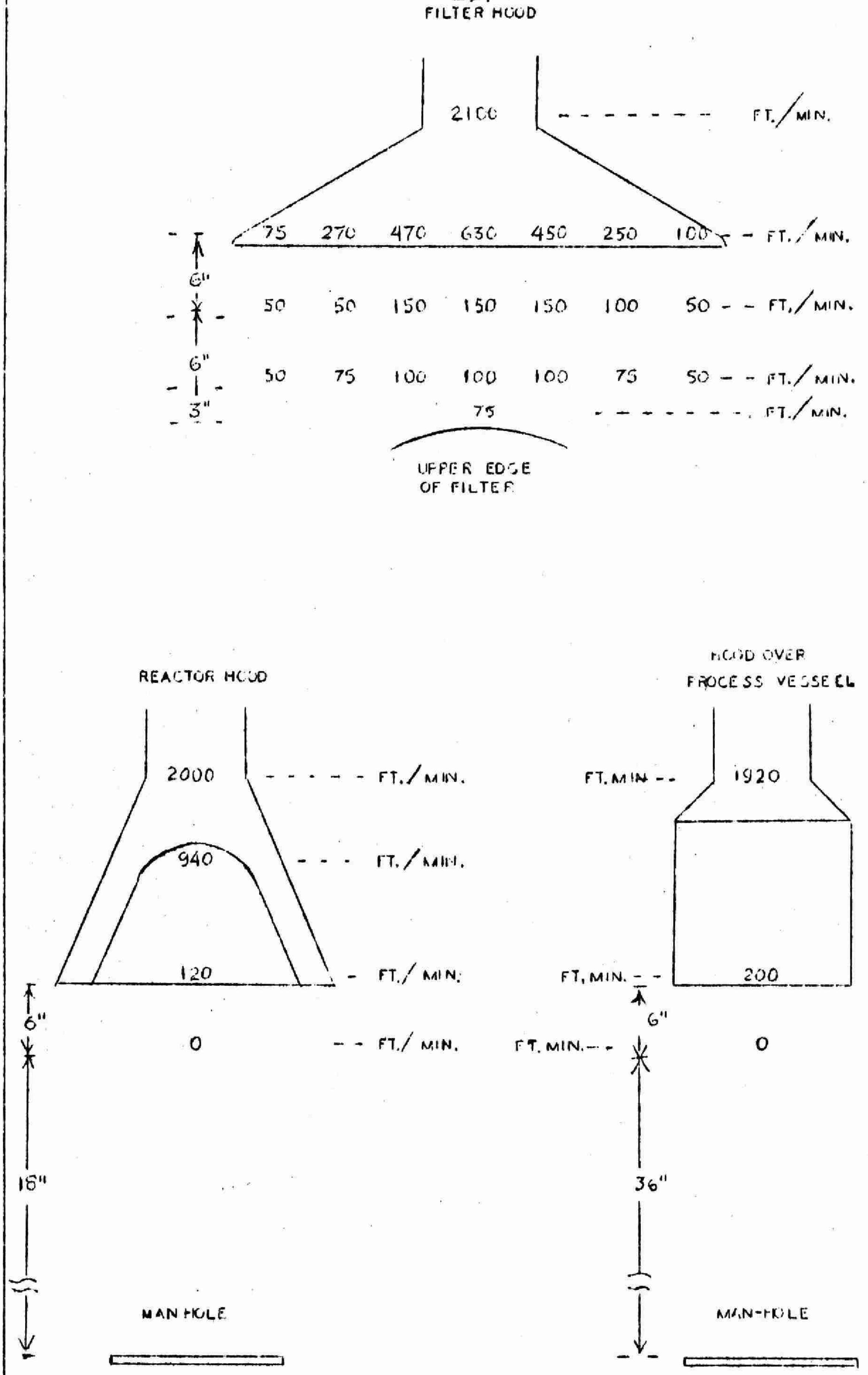
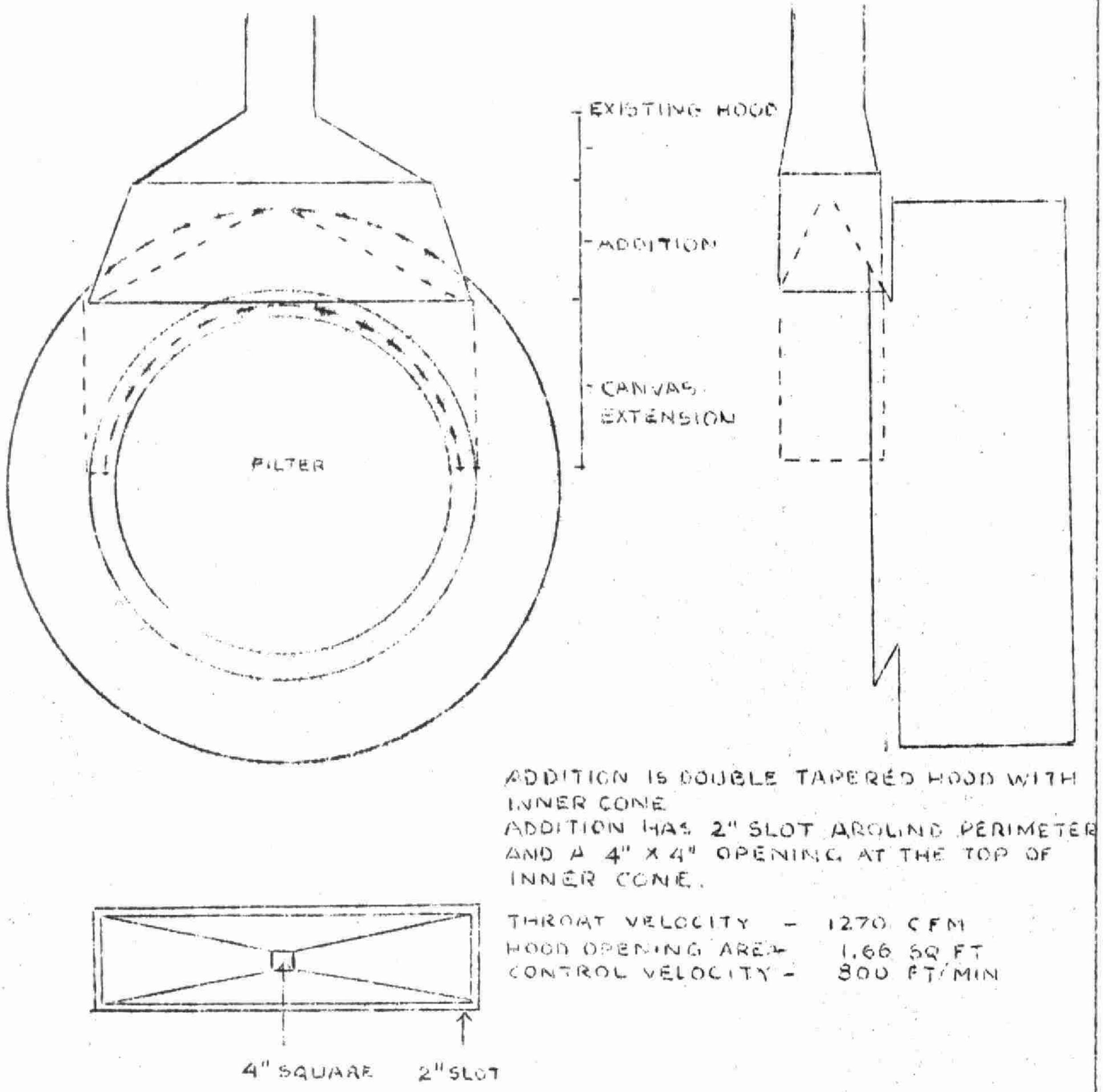


FIGURE 2 — HOOD EFFICIENCIES

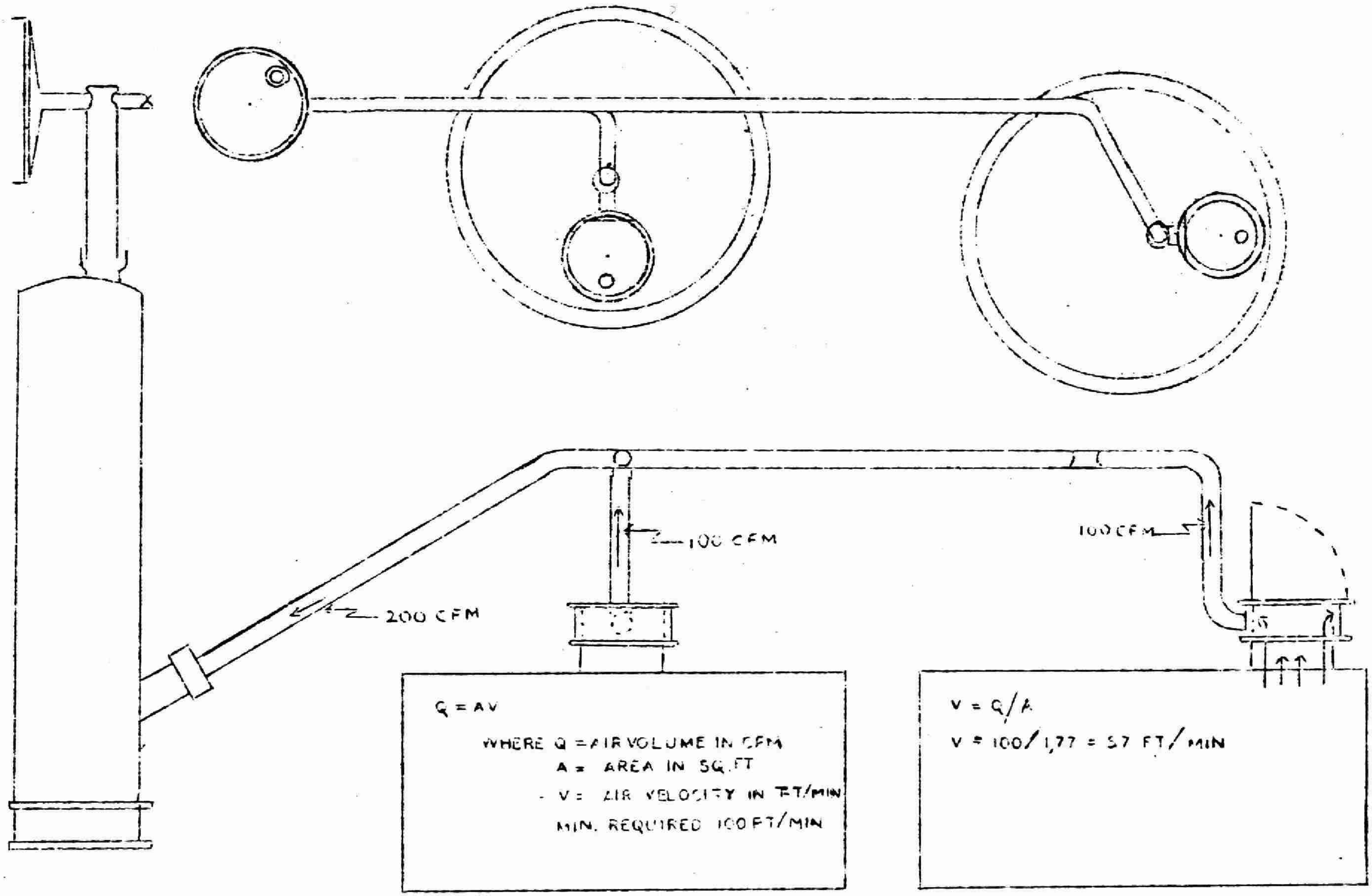
SCALE: 1" = 12"



ADDITION IS DOUBLE TAPERED HOOD WITH INNER CONE.
ADDITION HAS 2" SLOT AROUND PERIMETER AND A 4" X 4" OPENING AT THE TOP OF INNER CONE.

THROAT VELOCITY - 1270 CFM
HOOD OPENING AREA - 1.66 SQ FT
CONTROL VELOCITY - 800 FT/MIN

FIGURE 3 – FILTER HOOD EXTENSION
(SCALE-1" = 24")



Q = AV

WHERE Q = AIR VOLUME IN CFM
A = AREA IN SQ.FT
V = AIR VELOCITY IN FT/MIN
MIN. REQUIRED 100 FT/MIN

V = Q/A
V = 100/1,77 = 57 FT/MIN

FIGURE 4 = FUME ABSORPTION SYSTEM

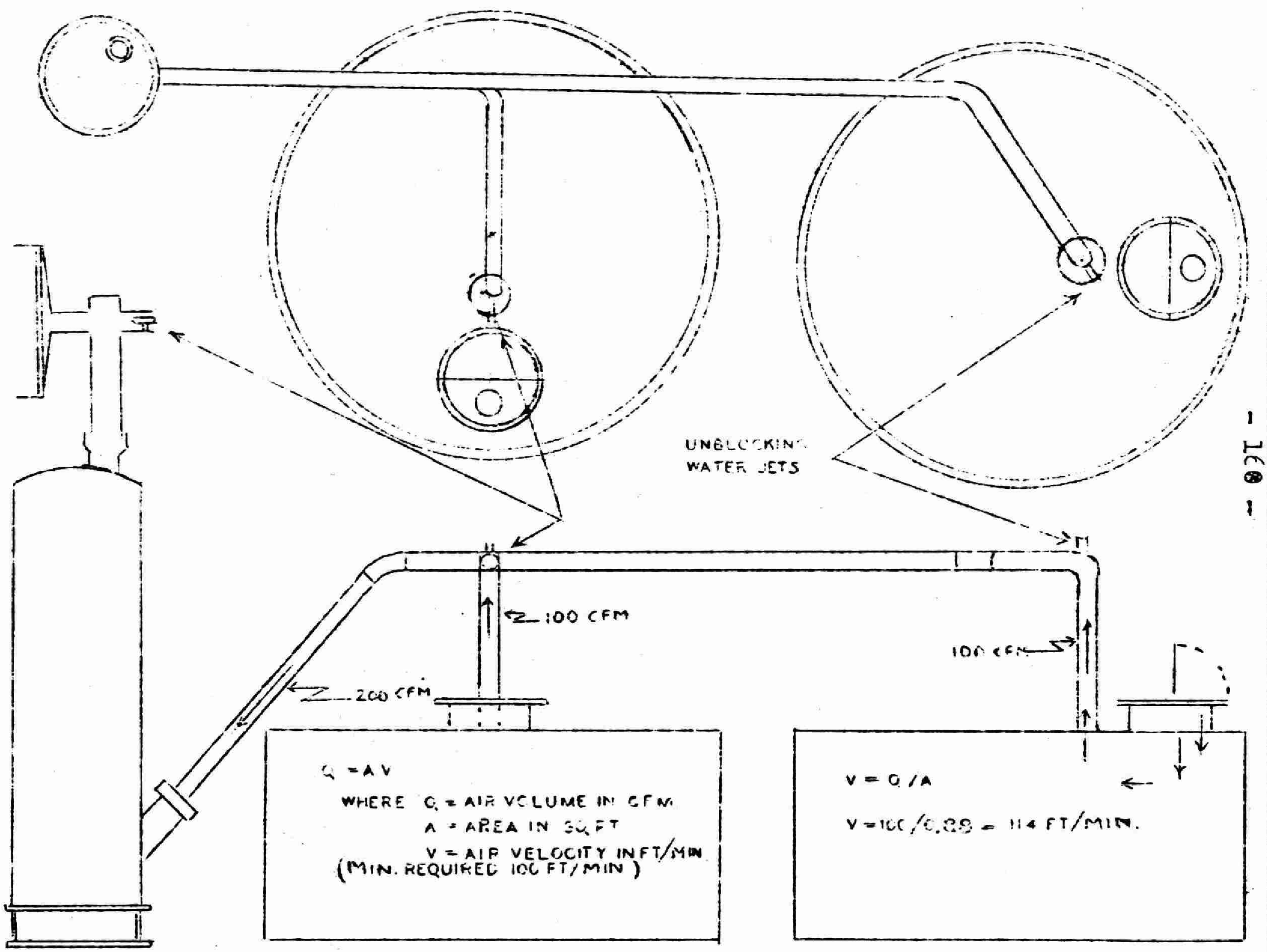
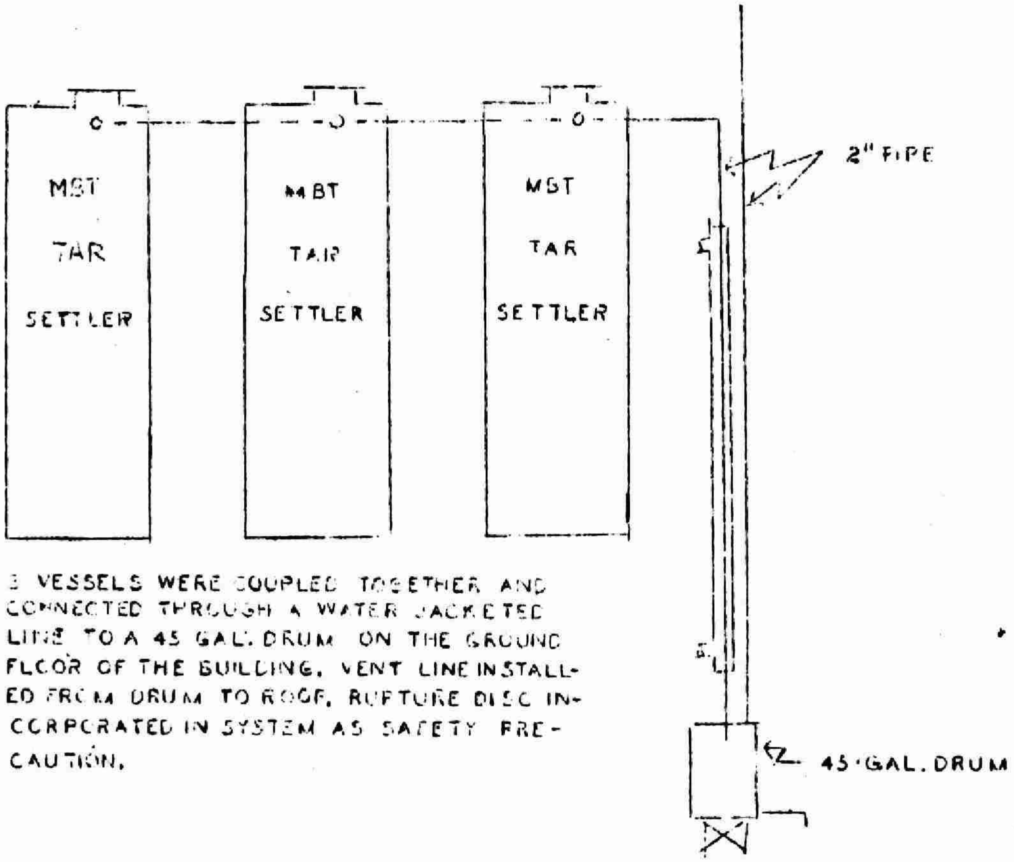


FIGURE 5 — FUME ABSORPTION SYSTEM



3 VESSELS WERE COUPLED TOGETHER AND CONNECTED THROUGH A WATER JACKETED LINE TO A 45 GAL. DRUM ON THE GROUND FLOOR OF THE BUILDING, VENT LINE INSTALLED FROM DRUM TO ROOF, RUPTURE DISC INCORPORATED IN SYSTEM AS SAFETY PRECAUTION.

FIGURE 6 -- ODOUR CONTROL

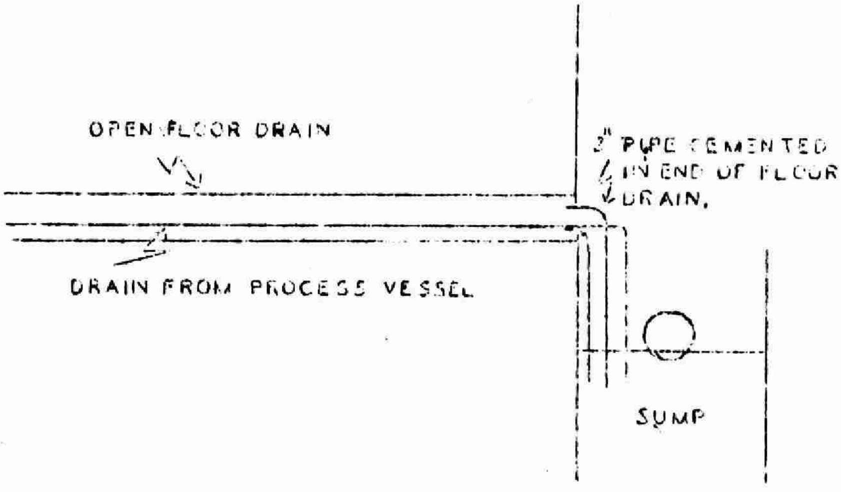


FIGURE 7 — ODOUR CONTROL

TABLE I

CHARACTERISTICS OF PLANT WASTE WATERS

	Weak Phenol Waste			Strong Phenol Waste		
	Min.	Max.	Av.	Min.	Max.	Av.
Flow, IGPM	8.0	12.8	9.8	1.0	1.5	1.3
Phenol, ppm	2.0	50.4	12.2	470	4,230	2,510
Phenol, lb. per day	-	-	2	-	-	43
COD, ppm	7	128	92	3,663	11,532	7,082
COD, lb. per day	-	-	13	-	-	122
pH	3.2	5.9	5.3	5.2	9.9	9.0

	2,4-D Waste Water			General Plant Wastes		
	Min.	Max.	Av.	Min.	Max.	Av.
Flow, IGPM	7.5	13.2	10.0	40	150	84
DCP, ppm	1,300	1,700	1,530	-	-	-
DCP, lb. per day	140	320	190	-	-	-
BOD, ppm	1,300	3,700	2,400	100	541	280
BOD, lb. per day	-	-	350	-	-	340
Inorganic salts, %	3.1	6.4	4.7	-	-	-
pH	1.4	1.9	1.6	6.7	8.0	7.4

	Aniline Waste Water		
	Min.	Max.	Av.
Flow, IGPM	2.0	2.4	2.1
Aniline, ppm	400	5,700	3,300
Aniline, Lb. per day	12	197	101
Nitrobenzol, ppm	200	2,400	1,600
Nitrobenzol, lb per day	6	83	53
BOD, ppm	4,434	12,076	8,970
BOD, lb. per day	-	-	270
pH	4.0	5.0	4.5

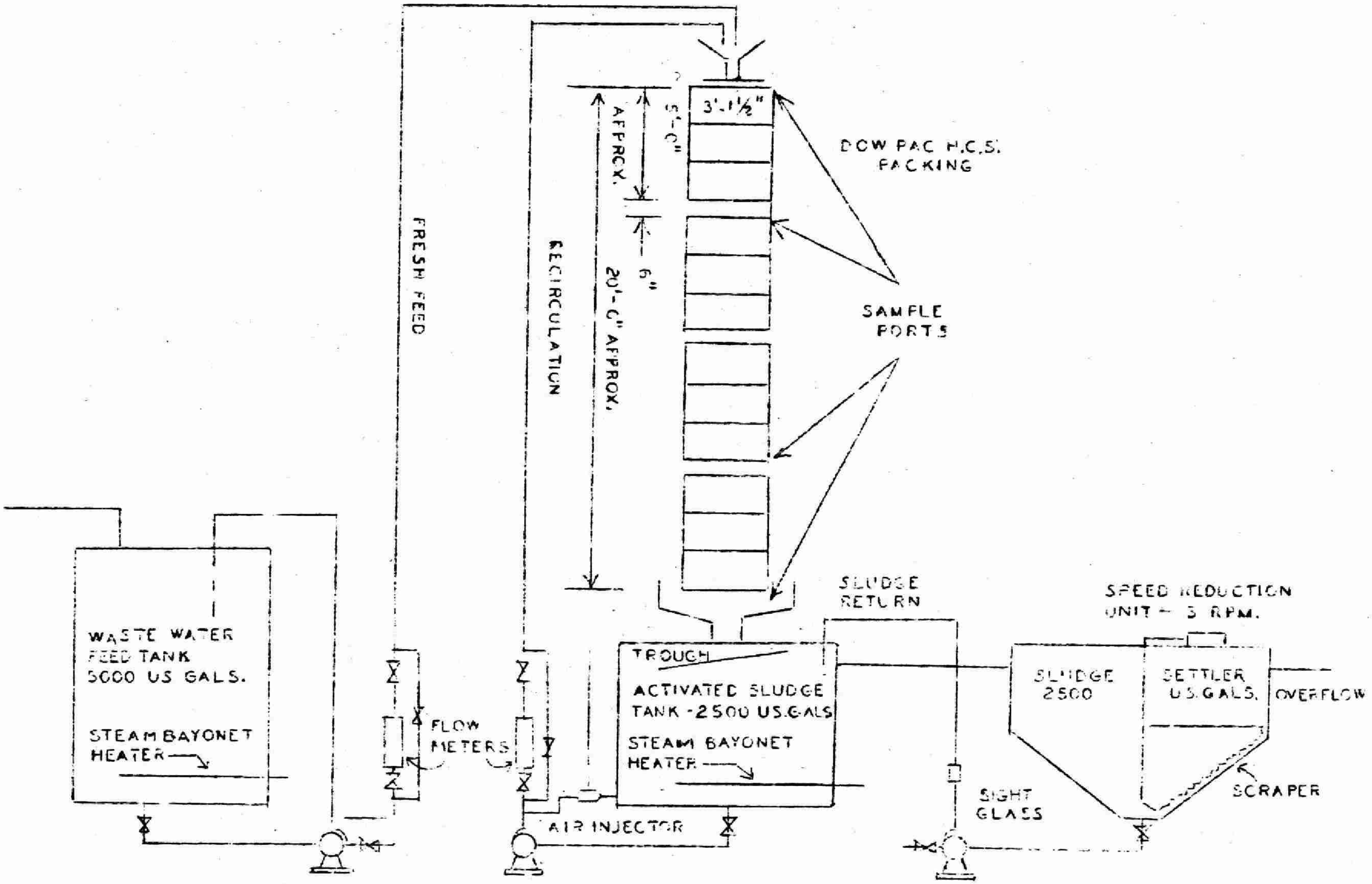


FIGURE 8 - PILOT PLANT BIO-OXIDATION TRICKLING FILTER

TABLE II

BLDG. 25 & 28 PHENOLIC WASTE WATER

October - 1957

	Influent			Bottom of Tower			Average Percent Removed	Effluent			Average Percent Removed
	Min.	Max.	Av.	Min.	Max.	Av.		Min.	Max.	Av.	
Flow, I.G.M.	1.0	5.0	3.2	22.0	26.0	24.6	-	2.0	6.0	4.6	-
Flow, pH	5.1	10.3	8.2	-	-	-	-	5.9	8.2	7.3	-
Phenol, PPM	95	500	240	0.0	20.2	7.5	-	0.4	1.2	0.8	-
Phenol, Lbs per day	4.9	23.8	12.0	0.0	0.95	0.29	96.9	0.02	0.07	0.04	99.5
COD,PPM	250	1424	730	59	186	102	-	25	114	57	-
COD,Lbs.per day	15.6	52.9	32.7	3.0	7.0	4.8	81.9	0.7	3.8	2.4	95.3

	Min.	Max.	Av.
Recirculation, IGPM	20	20	20
Recirculation,Ratic	3.3	10.0	4.6
Temperature, °F.	74	83	80
Phenol Destroyed in Tower, Lbs. per day	4.8	22.8	11.7
Phenol Destroyed, Total Lbs.per day	4.9	23.0	11.8
COS Destroyed in Tower, Lbs.per day	8.6	48.3	27.8
COD Destroyed, Total Lbs.per day	13.2	49.5	30.3

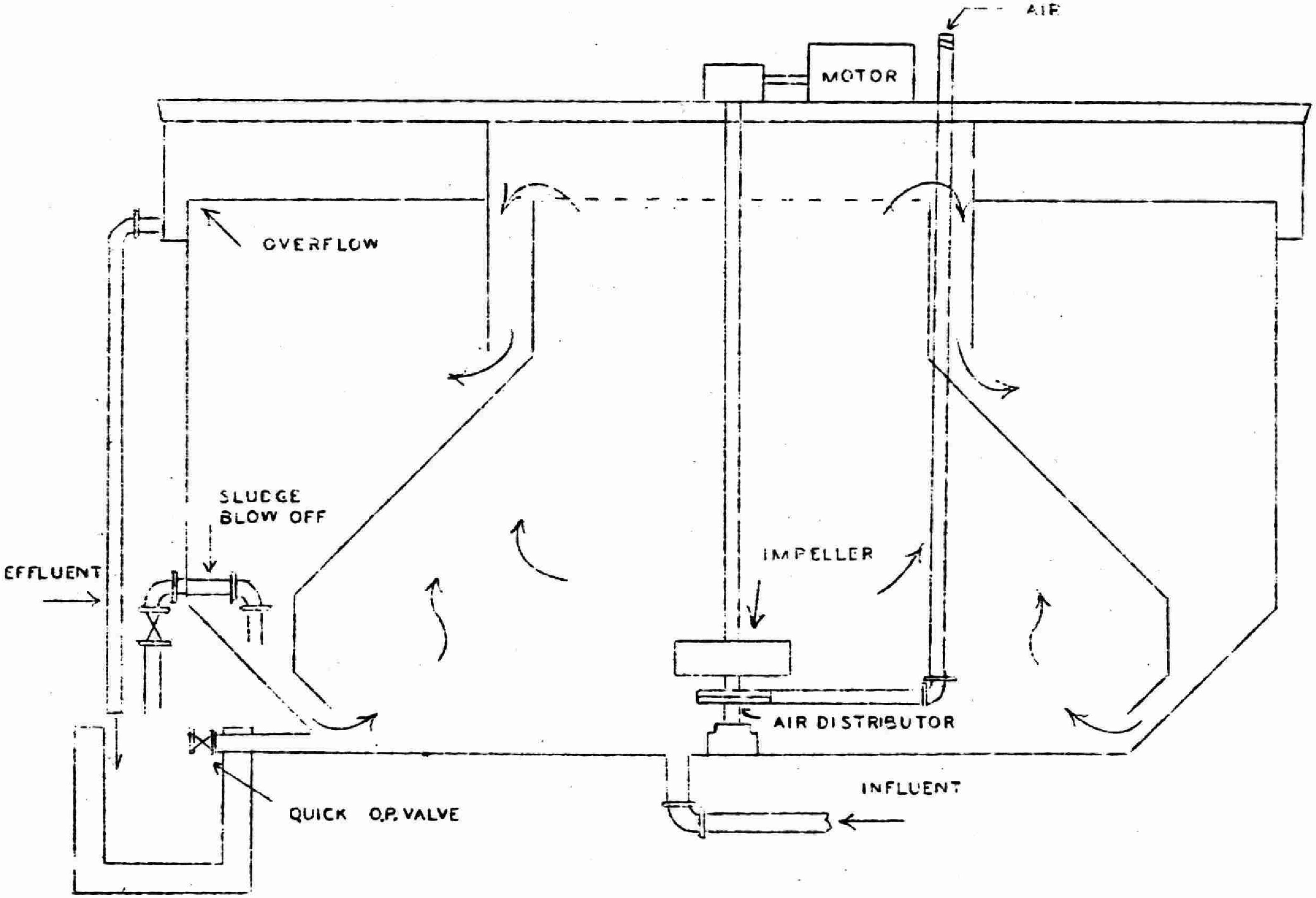


FIGURE 9 — INFILCO AERO - ACCELATOR

AERATION VOLUME - 17 CU. FT.

A STUDY OF FUELS AND COMBUSTION PROBLEMS IN AIR POLLUTION CONTROL IN THE MUNICIPALITY OF METROPOLITAN TORONTO

DEPARTMENT OF WORKS

AIR POLLUTION DIVISION

****

Over 95% of all air pollution comes from combustion processes, namely, heating and power plant equipment, incinerators, vehicles, locomotives, shipping, portable engines and open fires. There are, of course, numerous other sources of air pollution, such as dusts, gases, fumes and vapours from the handling of materials, packing plants, chemical plants, roads, etc.

For a better understanding of the problem, the fuels and waste materials consumed in Metropolitan Toronto, as estimated for the year 1957, are listed in Table 1.

A heat equivalent in British Thermal Units is included for ease in making a comparison between solid, liquid and gaseous types.

These fuels, and the equipment in which they are consumed, are changing so rapidly that it may be said that a major revolution is taking place. Within the past 10 to 15 years, domestic as well as commercial and industrial heating and power plants have changed largely from coal to oil as a fuel. The use of natural gas is also rapidly increasing. The coal interests are endeavouring to maintain their position in the field by intensified research to improve the process of combustion and by providing information services to users.

The normal products of combustion are carbon dioxide and nitrogen. Special products of combustion are sulphur dioxide and oxides of nitrogen--the amounts dependent, in the case of the former, on its content in the fuel as an impurity and, in the case of the latter, on the temperature of combustion.

Where combustion is incomplete, products are carbon monoxide, formaldehyde, other aldehydes, hydrocarbons and tars. Solid incombustible impurities, in both solid and liquid fuels, are emitted in the form of free carbon (soot) and fly-ash.

Other contaminants in the fuels from certain specific areas include arsenic, fluorine and lead.

Sulphur--the most serious and objectionable impurity--is inherent in all fuels, as itemized in Table II:

Table I

ESTIMATED ANNUAL COMBUSTION OF COMMERCIAL FUELS AND WASTE MATERIALS IN METROPOLITAN TORONTO (1957)

The figures presented in the following table are based on data available for the year 1956 and estimated for 1957:

	Estimated Quantity	Heat Equivalent Billions of Btu	Heat Equivalent %
(a) SOLID FUELS	TONS		
1. Bituminous Coal	1,560,000	43,680	23.5
2. Anthracite	110,000	3,080	1.7
3. Other	10,000	200	0.1
(b) LIQUID FUELS	Imp. Gals.		
1. Heavy Fuel Oils	92,000,000	16,560	8.9
2. Medium Fuel Oils	19,000,000	3,230	1.7
3. Domestic Fuel Oil	340,000,000	56,100	30.2
4. Stove Oil & Kerosene	12,000,000	1,920	1.0
5. Diesel Fuel	16,500,000	2,720	1.5
6. Gasoline	286,000,000	45,760	24.8
7. Lubricating Oils*	1,000,000	1,700	0.9
(c) GASEOUS FUELS			
1. Natural Gas	10,000,000 mcf	10,000	5.4
2. Propane	5,000,000 gal.	550	0.3
	TOTAL HEAT EQUIVALENT	185,500	100.0
(d) WASTE MATERIALS			
1. By-product fuels	data not available		
2. Selected Industrial Wastes	data not available		
3. Unclassified Waste	700,000 tons		

---

*Estimated quantity consumed in internal combustion engines.

Table II

	Sulphur Content
Bituminous Coal	2-3 plus %
Anthracite	0.5%
Heavy Fuel Oil	1-2 plus %
Medium Fuel Oil	1.0%
Domestic Fuel Oil	1.0%
Stove Oil and Kerosene	0.5%
Diesel Fuel	0.25%
Gasoline	0.25%
Natural Gas	0.5 gr/ccf
Propane	1.0%

During combustion, sulphur diozide (SO_2) and some sulphur trioxide (SO_3) are produced and discharged to the atmosphere.

Fly-ash nuisance is a function of the ash content of the fuel, the type of firing equipment, efficiency of dust collectors, if any, operating factors and other variables. For practical purposes, this may be stated only roughly in terms of application and ash content of the fuel:

Table III

	Assumed ash Content	% of ash discharged	% of fuel discharged
Central Power Plant	10.0%	1.0%	0.35%
Pulverized spreader fired industrial plants	10.5%	25.0%	1.75%
Locomotives	10.0%	75.0%	10.00%
Heavy oil installations	0.5%	90.0%	1.0%

Table 4 is a summary of industrial and commercial fuel-burning installations currently being installed:

Table IV

Fuel	% of Total	Approx. Horse Power Range	Approx. Heat Release	Approx. Smoke Range
			B.T.U. cu.ft.	Bacharach No.*
Coal	14	60-75	30 - 50,000	5 - 8.0
No. 6 Oil	19	75-200	30 - 80,000	3 - 5.5
No. 5 Oil	10	60-100	30 - 50,000	2.5 - 5.0
No. 4 Oil	4	60-90	25 - 50,000	2 - 4.5
No. 2 Oil	46	10-30	20 - 45,000	1.5 - 4.0
Gas	7	10-40	90 - 100,000	.5 - 1.5

Table IV - Cont'd

*Corrected to 12% Carbon Dioxide

(The Bacharach smoke tester is a small pump device which draws a specific volume of air through a filter paper, leaving a dark spot which is compared with a density chart having 10 shades, ranging from 0 (white) to 10 (black).

The tabulation given in Table 4 does not include the extremely low heat release rates of equipment still being installed by the conservative or "old school" suppliers; nor does it include the considerably higher rates shown in a few instances.

The lowest figure in the smoke range column is more than double that obtained with a good installation. Moreover, smoke numbers as high as number 9 have been observed, on occasion, with any type of fuel burning equipment, including gas, but invariably such a high figure is due to poor servicing rather than poor design.

It is interesting to note that, on many occasions, with a smoke number of 10 in the flue, little if any smoke is observed emitting from the stack. On the other hand, up to 10% of all recorded violations have been found due to black smoke pouring out of chimneys connected to oil burning equipment. In the latter case, it is probable that the equivalent smoke number might reach more than twenty times the minimum attainable, resulting in a high fuel loss and the discharge of an unnecessary amount of oily substance to the atmosphere.

A significant percentage of the fuel burning equipment presently being installed is not provided with adequate testing by the supplier--an unsatisfactory situation in view of the foregoing facts. However, this matter is receiving the appropriate attention of the Department.

"THE PRODUCTS OF COMBUSTION AND EFFECTS"

The estimated total and relative nuisance contribution of various fuels consumed in the Metropolitan Area are shown in Table 5.

The products of combustion may be a matter of concern, irrespective of whether there is complete or incomplete burning.

Sulphur Dioxide and Sulphur Trioxide

It has been determined that approximately 116,000 tons of these gases are discharged annually to the atmosphere within the Metropolitan boundaries, and careful tabulation can be made by the use of automatic recording instruments. Over the past few years, the sulphur content of certain fuels has increased, in some cases up to 50%, and the content of this matter in the atmosphere has been rising. The sulphur diozide and sulphur trioxide which result on burning form acid gases or cause reactions with other pollutants or substances, resulting in the formation of sulphates.

Table V

ESTIMATED TOTAL AND RELATIVE ANNUAL NUISANCE CONTRIBUTION OF VARIOUS FUELS

	SO_2		Fly-Ash		Smoke		CO
FUEL	Tons	%	Tons	%	Tons	%	Tons
Bituminous Coal							
(a) 500,000 tons	20,000	17	1,750	28	500	.5	--
(b) 60,000 tons	2,400	2	2,100	34	3,000	3	--
(c) 1,000,000 tons	40,000	34.5	500	8	25,000	26.5	--
1,560,000 tons	62,400	54	4,350	70	28,500	30	--
Anthracite							
110,000 tons	550	.5	100	1.5	550	.5	--
Heavy Fuel Oil							
92,000,000 gal.	17,400	15	1,750	28	14,500	15.5	--
Medium Fuel Oil							
19,000,000 gal.	1,600	1.5	--		1,400	1.5	--
Domestic Fuel Oil							
340,000,000 gal.	28,000	24	--		46,300	50	--
Diesel Fuel Oil							
16,500,000 gal.	350	.3	--		1,200	1	--
Gasoline							
286,000,000 gal.	5,700	5	--		--		915,000
Lubricating Oil							
1,000,000 gal.	--	-	--		1,500	1.5	
	116,000	100	6,200	100	93,950	100	915,000

Note:
(a) Central Station Power Plants
(b) Locomotives
(c) Other Uses of Bituminous Coal

No attempt has been made to include waste materials in the above table because of the variety of materials and conditions to be considered.

Concentrated sulphur dioxide will attack a wide variety of building materials, including limestone, marble and mortar. The carbonates in stonework are converted to relatively soluble sulphates and in the presence of rain water can be leached away slowly.

Paper may be embrittled by the action of sulphur dioxide and if concentrations are sufficiently high, the damage may occur within a two-week period.

Similarly, the life of such materials as leather, cotton, wool, and other textiles may be shortened. Nylon stockings are quite susceptible to rapid deterioration, since the threads are under considerable tension.

Recently, a relatively new awning was found decayed in spots; subsequently, determined to have been caused by soot from a nearby chimney, which contained an acid content in the vicinity of 10 to 15% on analysis.

In London, England, where considerable study has been made on leather, it has been found that safety belts which have deteriorated in a short period of time have contained as high as 6 to 7% of sulphuric acid. Furniture in clubs was observed to disintegrate rapidly, and leather book covers were damaged more quickly when exposed to the atmosphere than when confined inside glass bookcases.

Sulphur dioxide in sufficient quantities can cause damage to tender and sensitive types of vegetation, as may have been observed on growing trees which are located in close proximity to a main artery carrying heavy motor traffic.

Sulphur gases can also cause irritation of the throat, sinuses and lungs of certain persons through invisible dust particles that have been enveloped by high concentrations of the gas or its acid product.

Carbon Dioxide

To consider this gas as a pollutant will surprise most people, but it is an established fact that concentrations in a large municipality can be several times the so-called normal value. In the presence of moisture, this gas forms carbonic acid which attacks building stones and limestone, in particular.

Oxides of Nitrogen

These oxides are a product of high temperature combustion, produced particularly in central power plant operation and from high compression internal combustion engines.

They play a part in the photo-chemical reactions of any hydrocarbons in the atmosphere, and are of major concern in the city of Los Angeles, However, to date, there has been no cause for concern in Metropolitan Toronto.

Carbon Monoxide

Carbon monoxide results from the incomplete and improper combustion of fuel, particularly the type consumed in modern automobile engines. High levels of this gas can cause headaches in varying degrees. As the concentration of motor vehicles within a developed city increases, it is inevitable that the problem will become more acute. Research on this subject is contemplated at the present time.

Hydrocarbons

Approximately two million gallons of oil are consumed per day during the heating season, of which an estimated 2 to 3% or from 300,000 to 500,000 pounds of oily matter is discharged to the atmosphere.

From the million gallons of gasoline used daily throughout the year, an estimated 8%, or 320,000 pounds, is emitted unburned to the atmosphere. This is not known to be a matter of concern but, along with the oxides of nitrogen, may well become a problem requiring attention.

Tar from solid fuel-burning equipment adds a considerable amount to the hydrocarbon load and, like the oily matter from the fuel oils, is one of the reasons for the serious soiling and dirtying of clothing.

Aldehydes

Formaldehydes in concentrations as low as 50 parts per million can be irritating to the eyes, nose and throat. In part, they result from emissions due to imperfect combustion, particularly from incinerators and diesel motor vehicles.

This substance provokes one of our most serious types of complaint, and has caused new and severe regulations to be established in regard to the type of incinerator which is permitted in apartment installations.

Solid Particulates

The estimates tabulated in Table V reveal that approximately 18 tons of fly-ash are emitted daily from the chimneys of fuel burning equipment, which closely approximates the amount found in the dust fall tests that have been conducted.

Soot and tarry matter, as dark-coloured particulates, will soil white stonework and other light surfaces. Unless washed off by rain, the acidic nature of these substances will result in corrosion. The cleaning of building faces, besides involving considerable expense, results in further damage.

CONTROL OF EMISSIONS FROM COMBUSTION SOURCES

The satisfactory design of fuel-burning equipment as it pertains to combustion would comprise a treatise in itself. Over the years various types of equipment have been designed to give satisfactory combustion, but in some cases the problem of maintaining proper furnace temperatures, velocities and fuel-air ratios at various burning rates has not been solved and is not likely to be solved for some time. Research and new designs for fuel consuming units has resulted in higher efficiencies and at the same time has presented new problems which must be solved.

One of the most serious sources of pollution (about 25% of the total) is the domestic oil burner, of which there are approximately 300,000. In addition to having an actual stack smoke density several times higher than the reasonable minimum value, it has been found that a significant percentage have been installed in undersized furnaces or boilers. One might ask "why be concerned with furnace size?". The answer is that an undersized furnace increases heat loss up the chimney due to extra fuel being consumed which results in more sulphur and carbon dioxide being emitted to the atmosphere than would normally be necessary. The additional fuel also results in more soot and oily matter being discharged, While $30 or $40 might be saved in the case of an original installation by using an undersized furnace, it has been estimated that the fuel bill each and every year thereafter is increased by approximately this amount of money.

By far the largest proportion of domestic heating plants have been installed by reputable firms with the appropriate sized furnaces, but there are some cases where the smallest sized plant obtainable has been installed in order to reduce cost. In order to control this situation it is desirable to approve plans for domestic heating installations as well as to promulgate regulations governing the servicing of such equipment. This particular matter is under consideration at the present time in several large cities on this continent, including Metropolitan Toronto.

Such regulations when considered might include a maximum permissible smoke number, a limitation on the viscosities of oil to be used depending on the type of burner, stack size design to ensure sufficient properly distributed combustion air, minimum oil temperatures for proper atomization, and requirements for servicing, testing etc.

The desirable and appropriate time to plan air pollution prevention is during the purchase or installation period. It is an established fact that undersized or unsuitable equipment once installed or purchased is rarely changed being, in practically every case, retained until it is worn out or obsolete.

The plan approval and permit branch of any air pollution control department is the medium by which effective control is achieved and maintained. The rejection of inferior products that may cause nuisances and pollution always meets with opposition. However rigid enforcement of carefully planned standards is amply justified to the purchaser and to the public.

The locomotive present one of the most serious problems which must be faced. Steam is being replaced by diesel power but this alternative can be a serious offender and some types might be quite offensive. There is evidence that electrification, though high in capital cost, is lower in total cost. Certainly from an air pollution stand point, the electric locomotive is desirable particularly when operating inside the boundaries of large cities. Some research has been carried out on this subject in the past, but an intensification of effort is indicated.

Diesel trucks are most serious offenders when they are overloaded or lugging. Such vehicles, if powered on the low side, lug in high gear or hold up the traffic if the gear ratio on a grade is not changed. In Metropolitan Toronto there are many long grades of a type that do not exist in Detroit where the vehicles are manufactured and where they are, nevertheless, a problem. In Metropolitan Toronto engines of higher horsepower in some instances may have to be provided to enable this type of vehicle to climb grades satisfactorily without leaving long trails of black smoke. In addition, certain diesel engines of a cycle or manufacture proven to be an offender may have to be placed on the prohibited list.

With respect to incinerators the Select Committee of the Ontario Legislative Assembly which completed its findings in April 1957 stated that serious consideration should be given to the incinerator problem, if any are to be permitted. Research is being conducted on an extensive scale in several American centres and it is reasonable to expect that a completely satisfactory design will be forthcoming in the future. In the meantime, most cities like Metropolitan Toronto have adopted standard which are permitting progress toward the ultimate objective.

Many apartment incinerators are extremely obnoxious even when the effluent is virtually invisible. Unlike heating and power equipment, which are absolute essentials to our existence, the apartment incinerator for the destruction of garbage must be recognized as a convenience, there being in most cases some type of alternative method of disposal. For this reason, only incinerators of a type which has demonstrated satisfactory operation should be permitted within concentrated areas.

In the future motor vehicles should be equipped with anti-smog mufflers or such other devices as may be perfected. Some research in respect to this subject has been carried out to date but the final answer has not been achieved. It is imperative that research and development of control equipment continue at an intensified rate.

Heating and power plant fuel-burning equipment is rapidly changing over to the packaged or prefabricated type. As such there is a greater uniformity of product than heretofore and the results can be predicted much better. Our experience is that no matter how good the design they can and will get out of adjustment quickly causing unnecessary smoke. The Electronic Smoke Indicator and Alarm is, therefore, a piece of equipment that should be included in all specifications for major combustion units.

The height of stacks is a matter of concern to everyone and the subject is receiving concentrated study. Until recently chimneys were designed only from the standpoint of providing draft for combustion, but now a major protion of all industrial and commercial installations employ forced or induced draft. The high stack, formerly employed, was usually at a sufficient level above ground to handle the air pollution problem. Now extreme care must be taken to ensure new stacks are not permitted to discharge their effluent too close to ground level.

"High stacks are expensive but so is the damage and injury done by low stacks."

A simple, conservative rule formulated in Toronto is that a stack or chimney extend 5 feet plus 5 times its diameter above the roof on which it is located or above any nearby or adjoining roof, Such a rule, however, requires modification in special circumstances such as for central power plant from which several tons of fly-ash and sulphur dioxide may be emitted daily.

A single high stack for this purpose may cost several hundred thousand dollars but the citizens may suffer an equivalent amount of damage from a low stack over a ten year period.

A matter of this importance requires thorough consideration with complete meteorological and wind tunnel tests to ensure that the right decision is made in the planning stages.

The disposal of municipal and industrial wastes within a developed community presents a Municipality with one of its most serious problems. In some cases the development of sanitary land fills eliminates problems which might arise from the installations of municipal incinerators. On the other hand, space limitations may dictate that large refuse incinerators be used, in which circumstances it is essential that they be provided with the proper equipment to sterilize to as great an extent as practicable the effluent which is discharged to the atmosphere. In many instances considerable refuse is destroyed by open fire but the establishment of appropriate incinerators, combined with an effective pick-up, should eliminate the necessity for this type of combustion which is always a nuisance to adjacent citizens.

AIR POLLUTION CONTROL IN ONTARIO

- by -

D. A. Thomas, B.A., (Cantab)

Physicist, Air Pollution Control Branch
Ontario Department of Health

1. What is Air Pollution?

The air we breathe is a mixture of several gases and has a relatively constant composition; this is the environment in which all living organisms have their being. Air pollution occurs when any substance (solid, liquid or gas) is added to this mixture in sufficient quantities to cause discomfort or endanger the health or safety of persons, injury to plant or animal life, or damage to property. Some air pollution occurs naturally such as radioactivity, volcanic ash, smoke from forest fires or pollens, but in this paper we shall be concerned with pollution caused by man-made activities, and the controls imposed on them.

2. Historical Development.

The most important air contaminants in modern communities are made by the combustion of fuel. Historically, complaints concerning smoke date back to the 13th. Century in England and the proclamation issued in the reign of Edward I, banning the use of coal in London while Parliament was sitting, is the first known air pollution control act. On this continent, the first control by-law was passed in Chicago in 1881, although private litigation with regard to smoke was recorded at St. Louis as early as 1864. In Ontario, the earliest by-law was passed by the City of Toronto in 1907 (4941) and this was enforced as shown by the imposition of a $50 fine on an offending firm in the following year.

In Ontario, all municipal air pollution by-laws till 1958 derived their authority from the enabling legislation in the Municipal Act, R.S.O.1950, Sections 388 and 399, which specifically gives all municipalities the right to control the emission of products of combustion, to inspect and license all combustion appliances, and to fine offenders. None of these controls apply to "a furnace or fire used in connection with the reduction, refining or smelting of ores or minerals or the manufacture of cement, brick or tiles or to dwelling houses except apartment houses".

Other pollution sources such as the national railways and shipping come directly under the control of the Federal Government. For railways, the Board of Railway Commissioners for Canada, General Order No. 18, Nov.25,1908, forbids "the unnecessary and unreasonable emission of dense smoke in any city, town or village". It limits the emission of dense smoke to six minutes in any hour, if a new firebox is being built or cleaned, and to one minute in ten minutes for a steam locomotive standing in any yard or station. This order, however, is only in force in those cities which have air-pollution by-laws and it does not apply to locomotives on steep grades such as at Scarborough and Hamilton. Consideration is now being given by the Railway Commissioners to amending this order to one more fitting to modern conditions, but the point to remember is that the enforcement of the order is still the prerogative of the railways and is not the function of provincial or municipal officials. There is no Federal law governing the emission of smoke from vessels at present.

Events in recent years such as the Donora disaster (1948) when twenty deaths were attributed to air pollution, caused a rapid increase in air pollution control by-laws in the United States; in Great Britain, after the London smog episode (1952) where 4,000 deaths were caused by smog, public feeling was sufficiently aroused to enable the enactment of The Clean Air Act 1956, a bill prepared by The Beaver Committee, the last of a series of select committees convened in the last 100 years by the Government in power to study air pollution. Some of this feeling has infected us here in Ontario; our rate of industrial expansion is increasing, and our economy, which at one time was predominantly agricultural, is now mainly industrial. The problems which the longer established industrial communities of Britain and the United States face to-day will be ours to-morrow. With a view to obtaining first hand information of pollution problems in this Province, the Government appointed a Select Committee in April 1955; a Provincial election intervened in the summer of 1955 and in September 1955, a second Committee was appointed to study the problem of smoke and air pollution.

3. Air Pollution in Ontario.

The Select Committee was appointed with the following terms of reference: "to examine existing legislation and practice in relation to smoke control and air pollution in Ontario with particular reference to the installation and maintenance of equipment to control smoke and air pollution and methods and ways of extending public information in connection therewith."

The Committee visited many large cities in the United States of America which have severe pollution problems and conducted open hearings in 28 municipalities in Ontario.

By far the largest number of complaints in Ontario municipalities were directed against smoke and fly ash; in at least five communities there was evidence of damage to plant life, including trees, flowers and crops, and other complaints included odour and eye irritation. There was evidence of property damage to fences and roofs, and in one case it was claimed that pollution caused a reduction in milk production in livestock.

The offenders were railways, shipping, smelters, chemical plants, government offices, hospitals, paper and roofing companies, food-packing plants, metallurgical industries, plastic plants, petrochemical plants, dry cleaners, dairies and many others.

In many municipalities, air pollution by-laws have been passed; we have records for 12 of them, but in all probability they do not number many more in the entire Province. These by-laws operate within the frame work of The Municipal Act, but generally, except in the larger cities (Toronto, Hamilton and Windsor) where full-time staff is available for enforcement, administration of the by-law is a part-time function of a city official who has other more important duties.

In Toronto and Hamilton, however, the municipalities maintain well-equipped laboratories, and the skilled staff to carry out surveys and implement their findings with effective control programmes. Both these cities were in favour of abolition of such exemptions as applied to foundries, cement and brick firms under The Municipal Act and all municipalities were in favour of more stringent Federal regulations against pollution by the railways and shipping. It is of interest to record that in the following three cities, extensive surveys are in progress which will lead to controls based on physical measurement of pollution levels.

In Windsor, the International Joint Commission, representing both the United States of America and Canada, has sponsored a survey of pollution levels in the Detroit-Windsor area, coupled with the effect of such levels on the health of the inhabitants and on vegetation. This survey has been in progress since 1949, and recent recommendations concerning the control of smoke emission from vessels plying the Detroit River have been presented to the Commission.

In Sarnia, a unique form of group research is in progress. Three petrochemical industries and the Provincial Government agreed to share the costs of an air pollution research programme which was initiated in October 1952. The number of industries in this group has now increased to ten, and since its inception, the survey has been conducted by The Ontario Research Foundation; this research has led to a voluntary introduction of controls by industry and increased co-operation for lessening pollution in this area.

In Hamilton, the Canadian Manufacturers' Association is sponsoring a three-year air pollution survey which started in October 1955. In this case, the cost is borne entirely by approximately sixty Hamilton industries and the work is being conducted by The Ontario Research Foundation. The first two years' research was devoted to pinpointing the sources and measuring the levels of pollution in the city; in the third year, with the completion of a stack sampling programme, enough data should be compiled to indicate where controls are likely to be most effective in reducing air pollution.

A recent newcomer to the air pollution survey field is the Hydro-Electric Power Commission, who has initiated a survey near the new Richard L. Hearne plant in Toronto; as the new power houses come into service, the continuing check of pollution levels in the area surrounding this plant will provide a useful guide as to what controls are desirable. Future plans are for on-site air pollution surveys before and after the installation of new Hydro-Electric power plants.

Another interesting development and one which bodes well for pollution control in this Province, is the enlightened attitude of some of the new industries towards pollution. We know of at least three new industries who have carried out on-site air pollution surveys before and after the erection of new plants and it is possible that this type of endeavour will increase for the large industries who locate new plants in this Province.

4. Air Pollution Control Act 1958.

The report of the Select Committee published in February 1957 led to the passing of Bill No.177, An Act to amend the Municipal Act on April 3, 1957; the purpose of this Act was to bring hitherto exempted industries such as foundries, cement plants and brickworks immediately under municipal control. This was an interim measure designed to help municipalities combat air pollution in the ten-month period before the next Parliamentary Session. In the following Session, Bill No.152, known as The Air Pollution Control Act, was passed on March 27, 1958 and this will come into effect when proclaimed by the Lieutenant-Governor.

This Act enables the Department of Health to engage consultants, make grants to universities for research in the field of air-pollution and assist municipalities in the preparation of air pollution control by-laws, in the development of an air pollution programme and in the training of local staff. The Department may also furnish advice, initiate investigations and recommend standard procedures in the field of air pollution. An Air Pollution Control Branch has been set up under the Division of Industrial Hygiene, Ontario Department of Health, to administer the Act. Space has been obtained including laboratory facilities to assist municipalities and to conduct research in the air pollution field.

This Act will enable municipalities to pass by-laws to control air contaminants from any source. In territories without municipal organization, the control of air pollution is the function of the Province.

Municipalities may act singly or enter into agreement with other municipalities on a cost-sharing basis to prohibit or regulate the emission from any source. Suggested limits for dense smoke are Ringelmann No.2, which may be permitted for four minutes in any half-hour, except in the lighting of new fires (Ringelmann No.3 for three minutes in any quarter-hour) or in the event of breakdown of equipment when greater latitude is permitted.

Incinerators, open fires and internal combustion engines are specifically named for pollution control.

Inspection, regulation and registration of all types of equipment which may produce air pollution come under municipal control with the exception of heating systems for private dwellings.

Municipalities passing air-pollution by-laws must set up appeal boards to ensure equitable enforcement of the by-laws. Violaters are subject to a fine of $100 for the first offence and $300 for second and subsequent offences.

All by-laws or a synopsis thereof must be published in the local newspapers; for the emission of products of combustion, and for air-contaminants other than the products of combustion, the by-law becomes effective 90 days and two years respectively after the date of publication.

Municipal officers may, however, permit deviations from the requirements of any air pollution control by-law.

All municipal by-laws written under this Act must be submitted to the Department of Health for review.

An exemption to this Act is the emission of sulphur fumes from smelters roasting nickel, copper or iron ores which comes under the Damage by Fumes Arbitration Act. This Act was first passed in 1924 and has been revised several times since, the last time in 1958; it empowers an arbitrator appointed by the Department of Mines to assess "the damage occasioned directly or indirectly to crops, trees or other vegetation by sulphur fumes arising from the smelting or roasting of nickel-copper ore or iron ore or from the treatment of sulphides for the production of sulphur or sulphuric acid, to determine the damage and to make an award".

5. The Economics of Air Pollution.

I have indicated above the development of air pollution control in this Province to the point it exists today; I have said nothing of the economics behind this development. The prosperity of the inhabitants of this Province depends largely on the growth of industry and their health and comfort demand that industrial pollution should be kept within bounds; when these limits are exceeded as they have been at times in London and in Los Angeles, strict air pollution laws and their enforcement become necessary. For this, the individual pays in municipal taxes the cost of enforcement and as a consumer he pays in the goods he buys a hidden charge for the cost of industrial control equipment. In the final analysis, it is the public who pays the fiddler and it is the public who must call the tune. As Sir High Beaver pointed out so ably in his paper "The Growth of Public Opinion" read at the First International Congress on Air Pollution in New York, March 1955, "good legislation is ineffective unless public opinion supports its enforcement".

The pressure of public opinion must be exerted at all levels; if municipality X has a pollution problem, the local residents must demand action from their elected representatives who have the power to pass and enforce by-laws. If the problem requires technical advice in this specialized field, they have the services of the Air Pollution Control Branch of the Province which has been established for this purpose.

Various estimates have been made of the direct economic loss due to air pollution in an industrial community. In Great Britain and the United States, the annual cost per person over the whole country has been quoted as $10; in the large cities, the cost is at least twice this amount. In Ontario, therefore, it would seem likely that in our cities the annual economic loss per person is between $10 and $20.

The cost of enforcement of air pollution by-laws in the larger cities of the United States is approximately 20 cents per person per year with a maximum of 35 cents per person per year at Los Angeles. In Ontario, it is estimated that enforcement at Toronto and Hamilton costs 15 cents per person per year, and it is suggested that local municipalities would do well to bear in mind some similar rate for their air pollution control programmes. This is a small amount in comparison with the total economic losses due to air pollution, or to the amount which could be saved by an effective control programme.

It is not quite so easy to suggest a suitable rate for expenditure on air pollution control equipment by industry. The Ontario Select Committee suggested a figure of 2 to 5% of capital investment as a reasonable outlay; the Canadian Manufacturers' Association maintained that it was not possible to standardize the cost for all industry; for some industries, a 2% capital outlay on control equipment would be too high, while in others, industry could and would spend up to 50% of capital on control equipment. In most cases, there is a fine balance in the equities involved but a discussion of this aspect is outside the scope of this paper.