limited strictly to edible oils but are applicable also to petroleum-type oils. We have installed a two stage system at a refinery in Oklahoma, where the first stage is designed to, and in fact does, remove hydrocarbon-type oils from the waste stream without the use of chemicals, and the second stage is used to clarify the waste water. The first stage returns essentially all of the available hydrocarbon materials to the refinery where they are reprocessed. The second stage has effectively eliminated a large ponding system for final treatment of the waste water before it discharged to a federal system.

The electrochemical process has proven effective in removing fats and oils without the aid of chemicals at a large packing plant. The flow at this plant is 1200 gal/min. Even though the waste stream is contaminated with manure, blood, and has a fluctuating pH, it is still possible to recovery fat down to a level of 20 ppm, and this fat then is augured directly to a melter for rendering.

A fat recovery system also has been designed for an edible renderer. The fats, oils, and greases are removed in this case in a single stage operation from a level of 3000-5000 ppm to less than 100 ppm. The recovered fat then is passed through a skimmings thickener where the concentration is increased from 10-45% of hexane extractables. Control equipment which is installed at this plant enables the system to operate essentially without attention.

The process also has been installed in an inedible rendering operation which was not in trouble with the sanitary district. This installation was made at the request of the owner strictly for economic reasons: the fats and oils are money and the recovery from the sewer is profits.

Treatment of vegetable oil refining wastes to conform to government regulation[1]

MOLLIE KAYE CANTRELL and HOWARD F. KELLER, JR., GBK Enterprises, Inc., Fullerton, California 92633

Historical and conventional methods for the treatment of vegetable oil waste water are described. The results obtained and the economics of the various processes for oil-water separation are reported. A process utilizing selective adsorption filtration is described. The new regeneration procedure for cleaning the filter media allows for its total reuse. The process produces effluent water which will conform to existing government regulations for oil content. Development of the filtration/regeneration process is described up to full-scale installation with test results.

INTRODUCTION

Food processing plants have, in general, been designed to include one or more effective methods for removing gross amounts of such pollutants as biological oxygen demand (BOD); solids; fats, oils, and greases (FOG); acids; and alkalies. In reference to the plant waste water stream; however, the main technological emphasis has been given to the recovery of valuable by-products, i.e. the pollution-control achievements have been a desirable, but nonessential, effect of the attempt to recover these reusable by-products.

SKIMMING

Gravity separation is employed as a by-product recovery and pollution control method almost universally by industries which have significant amounts of fats and oils in their waste water streams. The method usually involves the combining of the various plant waste water streams and dumping into a common separation station. The separation station consists of a large pit equipped with bottom sludge removal equiment and a mechanical skimmer for removing the floating oils and fats. There is also a drain for taking off excess water. This recovery method is subject to overloading during peak production periods, is quite frequently a source of offensive odors, and produces neither high quality reusable products nor acceptably clean water.

Operating costs for this type of equipment are relatively low, but, as seen in Table I, the effluent water is far outside current limits for concentration of pollutants.

DISSOLVED AIR FLOTATION

A much more recent improvement in the treatment of food processing wastes is a method known commonly as dissolved air flotation. This method is more effective than skimming but less effective than some other known methods. Basically, the treatment consists of releasing pressurized air into a nonpressurized tank containing the waste water. The tiny air bubbles formed by this action will attach themselves to the dispersed grease and oil droplets and to the suspended solids (SS). This will tend to rise to the surface more rapidly and completely than in a simple skimming tank. Heavier solids will still fall to the bottom.

The results, shown in Table II,

TABLE I

Typical Results of Skimming Method (1)[a]

Impurity:	BOD	SS	FOG
Input	4010	3680	3985
Output	2440	2700	3200
Percent removal	38	33	25

[a]BOD = biological oxygen demand, SS = suspended solids, and FOG = fats, oils, and greases. These are given in ppm.

TABLE II

Typical Results Using Dissolved Air Flotation (1)[a]

Impurity:	BOD	SS	FOG
Input	2625	2225	1485
Output	1760	1507	560
Percent removal	33	32	62

[a]BOD = biological oxygen demand, SS = suspended solids, and FOG = fats, oils, and greases. These are given in ppm.

TABLE III

Results Using Alum and Polymer Combined with Dissolved Air Flotation[a]

Impurity:	BOD	SS	FOG
Input (from skimmer)	2440	2706	3195
Output	740	400	360
Percent removal	70	84	88

[a]BOD = biological oxygen demand, SS = suspended solids, and FOG = fats, oils, and greases. These are given in ppm.

[1]One of seven papers presented in the symposium, "Ecology—Practical Solutions to Environmental Problems as Practiced in the Fats and Oils Industry" at the AOCS Spring Meeting, Mexico City, Mexico, April 1974.

TABLE IV

Direct Cost Comparisons for 500,000 Gal/Day Waste Water Treatment Systems

	Air flotation (with chemicals)				GBK Filter unit			
Cost factor	Required amount	Daily need	Unit cost	Total daily ($)	Required amount	Daily need	Unit cost ($)	Total daily ($)
Aluminum sulfate	500 ppm	2075 lb	6cent/lb	124.50	None	---	---	---
Polymer	2 ppm	8.3 lb	$2/lb	16.60	None	---	---	---
H_2SO_4 (concentrated)[b]	for pH 3-6	Maximin 12 gph	$60/ton	138.00	For pH 4 or less	---	---	138.00
NaOH (concentrated)	to neutral effluent	---	$60/ton	138.00	Same	---	---	138.00
Labor	1 man/24 hr	24 hr	$6/hr	144.00	4 Hr supervisory time/week	4/7 hr	8.00	4.57/day
Power	1370 kwh/day	---	$.015/kwh	20.55	1500 kwh/day	---	---	22.50
Steam[c]	3000 lb/	---	---	---	None	---	---	---
Disposal of oily sludge	gpd	---	$150/2100 gal	50.00	None	---	---	---

[a]For air flotation, the cost of treating 1000 gal water with chemicals is $1.27. For GBK system, the cost of treating 1000 gal water is $.69.
[b]Continuous use of acidulation waste water reduces acid consumption proportionately.
[c]Cost of steam varies according to the availability of excess steam in the facility.

TABLE V

Equipment Response to Various Treatments[a]

Treatment system	BOD	SS	FOG
Raw plant effluent	2635	1400	485
Anaerobic lagoon	475	580	105
Trickling filter	296	602	75
Final clarifier	125	110	35
Chlorine contact basin	60	90	15
Total plant (percent)	97	94	97

[a]BOD = biological oxygen demand, SS = suspended solids, and FOG = fats, oils, and greases. These are given in ppm.

indicate an improvement in grease reduction by using an air flotation cell, but the air flotation cell appears to perform ca. equally to gravity separation for removal of BOD and suspended solids.

The efficiency of the dissolved air flotation method of FOG, BOD, and SS removal from the waste water can be improved by the use of chemical flocculants and coagulants. In one test, alum and a synthetic polymer were used to enhance the performance of the method (1).

Table III gives the overall average results of an extensive series of tests using a combination of alum and polymer with dissolved air flotation. This test was performed simultaneously with the test for air flotation cells above, without chemicals.

Better BOD, solids, and FOG removal have been reported by some sources, when the chemical concentration is increased.

Table IV gives a cost analysis of this type of operation.

BIOLOGICAL OXIDATION

Biological oxidation methods sometimes are used for food processors as secondary methods for removing pollutants prior to discharging to a stream or sewer. Aerated lagoons, anaerobic lagoons, trickling filters, and activated sludge are commonly used methods, and all are familiar to vegetable oil processors.

These types of biological treatment systems can be efficient, but variable operating conditions, such as pH, temperature, and bacterial activity, can be difficult to control. Lagoons, of course, must be located out-of-doors and require considerable amounts of land area due to retention time requirements. All of the biological oxidation methods are subject to overloading during peak production periods, and any upset in operating conditions for the systems will require hr or days for correction.

In general, each food processing plant has not one, but a combination of methods for treatment of waste water. In one report (2), results were obtained by treating the raw plant effluent with the sequence of methods shown in Table V.

TECHNOLOGY OF POLLUTION CONTROL

As can be seen, all of the methods produce an improved waste stream. Unfortunately, government agencies now are requiring that the food industry reduce the total output of FOG, BOD, and solids even further. Regulations now in effect require FOG content of no more than 10 ppm in some cases. Other areas have FOG limits of 100 ppm or less. Surcharges are almost universally imposed on plants whose effluents contain a high BOD content. The application varies from state to state and from city to city but the effect is always to create an unnecessary added operating expense for the plant.

In the past, it has been economically unfeasible and politically unnecessary for the industry to be concerned with the removal of the very small remaining quantities of impurities in the waste water stream. Government standards were few and were not rigidly enforced, and the industry has been allowed to discharge relatively high amounts of pollutants with the waste water stream, while fines for violations were nominal.

Technology in industry has made tremendous advances in process improvements, increases in productivity, and efficiency. With the advent of stricter antipollution legislation by governments throughout the world, it also has become necessary for the vegetable oil industry, as well as other food industries, to seek solutions for their water pollution problems. Recent government imposed standards for FOG and BOD content of waste water are strict, and these are being enforced more stringently than ever before.

While the technology of pollution control has taken large strides in many problem areas, new ideas for methods of oil-water separation have been few. This is, of course, one of the more difficult problems in the area of water pollution control. Skimming of the gross amounts of oil in the waste water is still an effective and economical method for the removal of oil. However, the limits now being imposed and enforced by the government require a more complete removal of oil and BOD than mere gravity separation can afford.

Ca. 5-10 years ago at the time of the beginning of stricter government regulations, filtration began to be reconsidered as a possibility for an effective and economically feasible method of pollution control. For the removal of solids from liquids, the deep-bed filter always has been recognized as effective. It also is known that a granular type filter media used in a deep-bed filter can effectively remove minute quantities of oil from a water stream. However, the major drawback for using a filtration method for the separation of oil and water is that, until recently, there was no means whereby the filter media could be reused after it was saturated with the oil from the waste water stream. If the media has to be dumped each time the bed is saturated with oil, then the filtration method becomes very costly, even if highly efficient.

GBK PROCESS

Several years ago, a patent was issued for a method in which the filter media bed was cleaned by introducing solvent or steam into the media then passing it through the bed in the direction countercurrent to the liquid flow. For the petroleum industry, the above method for cleaning has proved to be satisfactory, and GBK has an agreement whereby they can sell this unique system.

GBK tried to apply the steam cleaning process to edible oil refinery water filters and was unsuccessful. The major problem encountered was due to the acitivity of the unsaturated oils compared to the petroleum oils. After several steam cleaning cycles, the filter media became cemented together by a highly polymerized varnish, caused by the steam cooking, and this was, of course, impossible to remove.

To avoid the above problem, a radical and novel method of chemical regeneration was developed and has become a part of the GBK oil-water separation process. This new process made feasible the use of a deep-bed filter with vegetable oil processors' waste stream. However, there were other important problems to be solved relating to the complete water pollution problems existing in the industry.

To arrive at the level of waste water purity desirable to conform to government regulations, it was necessary for GBK to develop a completely integrated, unique, water treating system for the edible oil industry. To this end, a process was developed which has the capability of removing and subsequently recovering virtually all of the fats, oils, and greases from an effluent stream. The heart of the treatment system is selective absorptive filtration combined with chemical regeneration of the filter media. The efficiency of the filtration method has been improved by GBK, by taking into consideration the many facets of the process. Each of these process areas was studied, tested, and changed, if necessary, to maximize the efficiency of the filtration process.

The first step in improving the filtration process was gaining an understanding of the theory of the selective adsorption process. The closest analogy to selective media filtration is chromatography. The mechanism is almost identical in that it is a surface absorption mechanism demonstrating a surface saturation migration potential, with total adsorptivity being proportionate to surface area. The only difference seems to be greater quantitative adsorption than would be dictated by the theory.

The quantity of oil adsorbed is a function of: (A) particle size distribution within the filter media, (B) flow rate thorugh the filter in gpm/ft^2, (C) oil content of the waste water stream, and (D) the effect of other constituents in the waste stream on the absorptivity of the oil.

As an example of the effect of particle size distribution, the following was observed in the quantity of oil adsorbed by two sands with the same mesh size nomenclature, but differing widely in their particle size distribution patterns. (Oil capacity of the bed was reached at the time oil breakthrough was observed in the effluent stream). The sands were both 30 mesh according to the suppliers, and flow rate was held constant at 10 gpm/ft^2. The feed fluid was refinery waste water containing 650 ppm FOG and 120 ppm solids (mostly bleaching clay). The two tests were run simultaneously so that variations in condition of the waste water feed stream could be ignored. Sand S retained 1.3 lb oil/ft^3 media at the time of oil breakthrough and sand M retained 6.8 lb oil/ft^3 media at the time of breakthrough. Equal volumes of wet sand were used for each test.

To demonstrate the effect of flow rate, the above beds were regenerated, and the flow rate was increased to 20 gpm/ft^2. Sand S retained 0.6 lb oil/ft^3 at breakthrough, with a pressure drop of 11 psi/ft media depth. Sand M retained 4.8 lb oil/ft^2 at breakthrough with a pressure drop of 5.2 psi/ft of media depth.

For all normal sand usage applications, the sands are identical. As a matter of fact, sand S is the most frequently used and most highly recommended, because it falls within the established National Filter Sand recommended ranges, while sand M does not.

The above noted differences in oil adsorption and throughput capacity in the two similar sand filter medias points out the necessity of properly designing the bed for the waste stream

TABLE VI

Plant Effluent Composition

Impurity source	Percent
Deodorizer water	91.7
Gravity separation basin	1.66
Water wash	1.66
Condensate	3.3
Acid waste water	0.83
Packaging	0.83

TABLE VII

Plant Effluent Response to Various Water Treatments[a]

	Feed		Product	
Sample number	FOG (ppm)	COD (ppm)	FOG (ppm)	COD (ppm)
1543	280	—	0.5	—
1608	815	2210	1.2	1580
1630	195	2340	2.8	1550
1700	260	—	2.6	—
1740	145	2930	39.0	1320
1810	750	2210	12.2	1060
1830	78	—	14.3	—
1900	60	—	19.4	—
2045	23.5	—	1.9	—
2115	16.7	—	0.6	—
2130	39.0	—	1.1	—
2145	39.0	—	0.2	—

[a] FOG = fats, oils, and greases and COD = chemical oxygen demand.

TABLE VIII

Fat, Oil, and Grease (FOG) Response to Treatment

Sample number	Pressure drop (lb)	FOG (feed) (ppm)	FOG (product) (ppm)
1630	15	45	12.7
1700	13	53	1.5
1754	14	3040	1.3
1803	15	480	0.9
1900	16	76	2.5
2000	24	49	1.6

in a particular situation rather than using a "universal" filter sand.

TEST DATA

Initial tests of the system of adsorptive filtration on refinery waste water were conducted on 1-3 gpm slipstreams of plant effluent waters or on streams deliberately mixed to simulate total plant effluent.

An experimental, small-scale filtration study was conducted at a vegetable oil refining facility to determine the FOG removal from treatment of a synthetic waste water which is representative of the plant effluent presently being discharged to the sewer. The plant effluent composition tested is shown in Table VI.

The average pH of this blended waste water stream was 4.5 with no significant change being affected by the filtration process. FOG for the feed to the filter was an average of 225 ppm. The average output of the GBK filter was 7.9 ppm. This represents an average reduction of FOG content of 96%. The filtration test period extended over a period of 3 hr, at a flow rate of 1 gpm. There were three 1/2 hr shutdown periods during which the media was either changed or regenerated.

The results from the test are given in Table VII.

Based upon the significant FOG and chemical oxygen demand (COD) reductions with the smaller 1-3 gpm pilot units, studies were planned involving the use of a 100 gpm skid-mounted unit. This filter was set up adjacent to the gravity separation basin which collected the total plant effluent before discharge to the sewer. Suction was taken from the "clean" water section of the basin.

Average input to the filter was 623 ppm of FOG. Ten min prior to taking sample 1754, 5 gal pure vegetable oil was injected into the line feeding the filter to see what increase, if any, in FOG output would occur. Average output of the filter was 3.4 ppm of FOG, representing an average reduction of 99.5% in FOG. The pH of the waste stream was adjusted to ca. 1.0 with H_2SO_4 injection, prior to filtration. Results of the test are shown in Table VIII.

Length of the experiment was 3-1/2 hr. The pump was shut off when pressure drop across the bed reached 24 lb. This had been predetermined to represent a state of undesirable solids plugging within the filter media. As seen above, FOG removal was good, even with a partially exhausted filter media.

At the request of the refinery management, a second test with the 100 gpm unit was conducted on a day when palm oil was being processed. Information desired was related to removal of SS, FOG, and COD. The first half of this test was conducted at the deodorizer basin and the second half was conducted at the gravity separation station. The pH was adjusted to below 4.0 in every case. Length of the filter cycle at each test station was ca. 1 hr. At the end of that hr, refinery personnel took two consecutive samples of feed and product water for analysis. Results were reported by an independent laboratory and are given in Table IX.

The successive steps of scale-up for tests were 1-3 gpm, 100 gpm, and 170 gpm. GBK recently has installed a full-scale plant for a Chicago facility of an edible oil producer on a waste water stream averaging 450 gpm of flow.

The operation is initiated by pressured flow from our effluent stream into two or three vessels containing adsorptive media. An automatic programer is set for a specific time cycle that controls the amount of time the two vessels receive this flow. The time cycle can be set for any frequency of 30 min-8 hr. At a preset time, one of these vessels is taken off stream, and the third vessel comes on stream. The off stream vessel is regenerated in a patented process that recovers the oil, which subsequently is returned to our fats acid stock. The off stream vessel then is backwashed to remove the entrapped solids, and the vessel goes on standby, having been regenerated without loss of adsorptive media. The next cycle of regeneration takes the second vessel off stream for oil recovery and solids removal. During the entire process, two vessels always are filtering and one is in regeneration or on standby.

The automatic programer is responsive to two other signals that monitor the quality of water from the GBK filter system. A signal from a turbidimeter which is monitoring effluent from the filter system can instantly override the preset time cycle and cause the standby vessel to come on stream and place in regeneration the vessel which has been longest on stream.

Secondly, a pressure differential increase signal from a pressure sensor can override the preset time cycle and act to remove the oldest vessel from the system for regeneration. The pressure override indicates excessive solids and oil buildup in the media bed and processes a clean vessel into service. These back-up override signals allow for 100% recovery by the system while maintaining the filtering efficiency in cases of severe loading by solids or oil.

The overall water treating system which has been installed is an 800 gpm capacity unit. It consists of the filter, pH control equipment, automatic valving, flotation vessel, pumps, minor peripheral storage tanks, and equipment. Initial performance tests have been conducted by both GBK and the customer. The GBK system has proved itself to perform within the limits imposed by the city and state with reference to FOG content and SS.

The importance of total automation of the system has been pointed out by the start-up problems encountered in using the system on a manual basis. The system involves a complicated sequencing of valves and other equipment to achieve best results during both the filtration cycle and the filter regeneration cycle. When manual operation is used, operator errors quite frequently upset the normal operation of the complex system of water treatment. This in turn produces poor average results from the treatment system. Automatic, programed controls eliminate the need for operators, decrease labor costs, and enable the filters to operate as guaranteed, without the uncertainty of human performance.

Also worth mentioning at this point is the necessity of customer control of the flow rates of waste water and the impurities in the stream which is fed to the waste water treatment system. Data are available which show that variations in plant operating procedures can influence the guaranteed

TABLE IX

Palm Oil–GBK Filter Test

Location	Product	Time	pH[a]	Suspended solid (ppm)	Hexane soluble (ppm)	COD[b] (ppm)
Deodorizer basin	In	1:30 pm	2.53	6.7	64	290
	Out	1:30 pm	2.60	Less than 1	Less than 5	33
	In	1:35 pm	2.54	1.5	50	250
	Out	1:35 pm	2.58	Less than 1	0.5	50
Gravity separation basin	In	2:57 pm	1.76	11.6	94	350
	Out	2:57 pm	1.56	Less than 1	0.5	75
	In	3:07 pm	1.68	2.2	168	570
	Out	3:07 pm	1.80	Less than 1	Less than 0.5	70

[a]pH was adjusted to below 4.0 in every case.
[b]COD = chemical oxygen demand.

performance of the filter system. For each individual plant, it is, therefore, necessary to make a specific evaluation of the waste water stream and the government standards which must be met. Then, we must institute plant operating changes and controls which will ensure consistency, within recommended limits, of the waste water feed to the GBK filter system.

The unit currently is being operated manually. Start-up data are incomplete at this time, but the following trends are clear: (A) surcharges for discharging the BOD to the city sewer have been reduced to a fraction of the former amount (from ca. $14,000 to $3,000 or less/month); (B) threat of fines for FOG discharge has been eliminated, as output from the filters falls within government standards; (C) oil recovered for resale has increased by 5000 lb/day over the old system (this oil has a current market price of 14.5 cents/lb); (D) the GBK unit performs as guaranteed when required operating conditions are fully met by the customer.

REFERENCES

1. Seng, W.C., in "Proceedings–Second National Symposium on Food Processing Wastes," Environmental Protection Agency, Washington, D.C., 1971, pp. 337-366.
2. Baker, Darrell A., and James White, in Ibid. pp. 289-312.

[Received July 5, 1974]

Operating experience with biological cooling towers[1]

WILLIAM M. NEUNER and **ERNEST K. HOLT**, Lever Brothers Company, New York, New York 10022

One of our major water pollution problems concerns the purification of, and disposal of or the bottling up of, waste water from our edible oil processing plant in Edgewater, N.J., and our fatty acids distillation plant in Hammond, Ind. It was decided to investigate the use of a cooling tower as a means of developing an environment for biota growth so that aerobic bacteria would feed on the organic matter present. This preliminary work was done in 1966 on a 30 gpm prototype tower in Hammond and a 720 gpm tower (modified) in Edgewater. As a result of this test work, Lilie Hoffman cooling towers, with high fill to volume ratio and abnormally large water basins, were purchased for our Edgewater plant and Hammond plant. The towers were commissioned in September 1972. The tower systems are fitted with the necessary controls to maintain proper basin water temperature along with automatic feed systems for the nitrogen and phosphorous required for satisfactory biota growth. The Edgewater tower, with a capacity of 3700 gpm, has performed satisfactorily with regard to chemical oxygen demand values and odor problems. There have been a few minor mechanical problems. The Hammond tower, with a capacity of 380 gpm, has had mechanical problems which have precluded sufficient continuous operation to assess its performance completely.

INTRODUCTION

In the refining of fats and oils for use in edible and soap products, high vacuums are employed. These vacuums generally are obtained by the condensation of steam in barometric condensers. Part of the process also may require steaming of the product simultaneously, and steam and organic vapors may be generated by the presence of a vacuum and heat. Therefore, the condensing water not only is heated; it picks up organic matter carried out as vapor or steam distilled from the reaction vessel.

One of our major pollution problems concerned either the purification and disposal, or bottling up, of this waste water, and studies were begun several years ago to solve the problem.

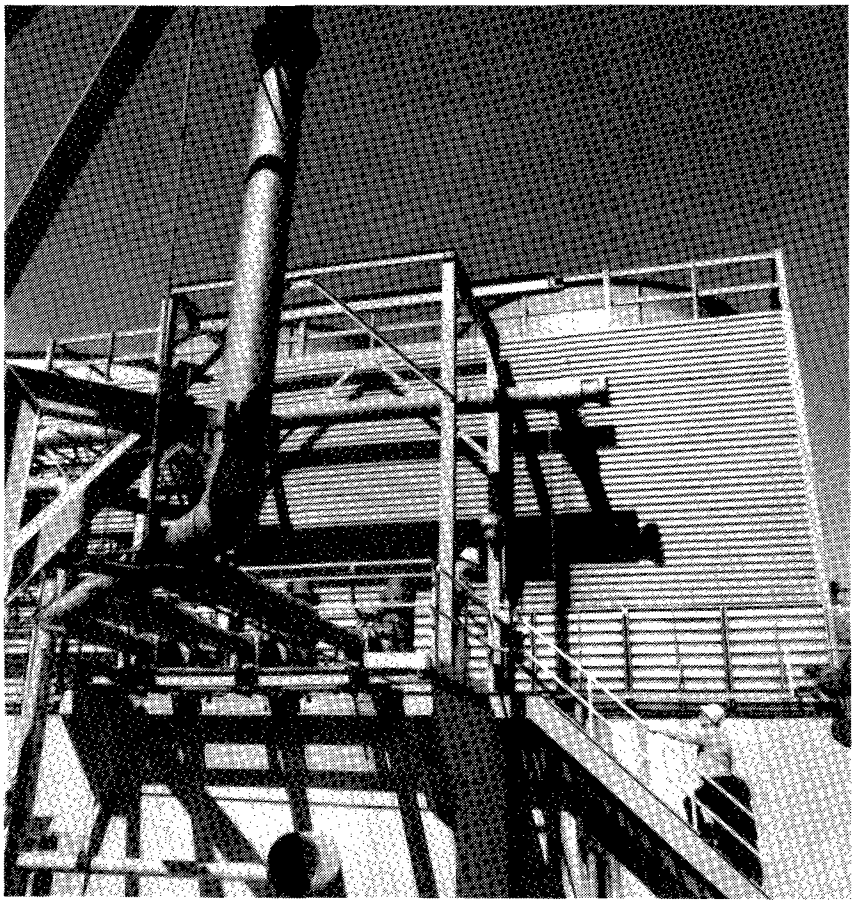

FIG. 1. Biological cooling tower shown under construction at Lever's Edgewater, N.J., plant. Piping in left foreground supplies water from cooling tower to edible process department.

[1]One of seven papers presented in the symposium, "Ecology–Practical Solutions to Environmental Problems as Practiced in the Fats and Oils Industry" at the AOCS Spring Meeting, Mexico City, Mexico, April 1974.