

SEWAGE WORKS JOURNAL

VOL. X NOVEMBER, 1938 No. 6

Special Articles

Use of Lime in Activated Sludge Process—Haseltine

Air Diffusion vs. Mechanical Aeration—Roe—Kappe

Sale of Sludge at Pasadena—Allen

Vacuum Filtration—Van Kleeck

Qualifications of Operators—Dappert

Filters for Phenolic Wastes at Dow Company—
Harlow, Powers and Ehlers

OFFICIAL PUBLICATION OF THE
FEDERATION OF SEWAGE WORKS ASSOCIATIONS



When Accessibility is Important...



MAYBE you've never been in the same predicament as our young friend above, but if you've ever operated a piece of mechanical apparatus, you've doubtless felt just as helpless while trying to make some adjustment or repair.

With a W&T Vibrole Chlorinator you don't have to see around corners or tie your back in knots to reach some hidden part. It's all out in the open, and every part is easily accessible without unscrewing, wrenching, or straining. Lift the bell jar and the complete mechanism is ready to your hand; you can see the float, the right side panels and all of the connecting pipe and hose lines are within easy reach.

Accessibility is important for the operator's peace of mind. It's important, too, for the safety of the chlorinator. The reason is simple. The W&T Vibrole Chlorinator has been and continues to be the world's most popular chlorinator for dependable, accurate and economical control of the chlorination process.

Write today for technical publications describing W&T Vibrole Vacuum Chlorinators.

"The Only Safe Water is Sterilized Water"

WALLACE & TIERNAN CO., Inc.

Manufacturers of Chlorine and Ammonia Control Apparatus
NEWARK, NEW JERSEY
Branches in Principal Cities



CHLORINATORS FOR WATER WORKS • SEWAGE PLANTS • SWIMMING POOLS • INDUSTRIAL PLANTS

4. R. F. Goudey, "Demonstration on Bulking and Debulking of Activated Sludge at Escondido Plant," *Calif. Sew. Wks. Jour.*, 5, 61 (1932-33).
5. R. C. White, "Cause of Bulking in Activated Sludge Plants," *Mun. San.*, 6, 380 (Dec., 1935).
6. P. E. Mauley, "Two Years Experience with Phoenix Activated Sludge Plant," *Public Works*, 65, 14 (Sept., 1934).
7. E. E. Smith, "Experiences with Chlorination of Activated Sludge," *Waterworks and Sew.*, 81, 362 (Oct., 1935).
8. H. E. Rhodes, "Effect of Iron and Chlorine on Activated Sludge Bulking," *Ibid.*, 83, 196 (June, 1936).
9. C. G. Anderson, "Activated Sludge Control at Rockville Centre and the Prevention of Bulking," *This Jour.*, 8, 784 (Sept., 1936); *Waterworks and Sew.*, 83, 342 (Sept., 1936).
10. T. R. Haseltine, "The Activated Sludge Process at Salinas, California, with Particular Reference to Causes and Control of Bulking," *This Jour.*, 4, 461 (May, 1932).
11. F. W. Mohlman, "The Sludge Index," *Ibid.*, 6, 119 (Jan., 1934).
12. Langdon Pearce et al., "Bulking of Sludge in the Activated Sludge Process of Sewage Treatment," *Am. Pub. Health Assoc. Year Book* 1935-37, p. 164.
13. H. M. Ely, "Problems and Their Answers at the Ontario Activated Sludge Plant," *Calif. Sew. Wks. Jour.*, 10, 17 (1938).
14. P. P. Morgan, A. C. Durdin, III, and M. Spiegel, "Sewer Flushing Prevents Bulking of Activated Sludge at Flora, Illinois," *This Jour.*, 9, 933 (Nov., 1936).
15. Jan Smit, "Bulking of Activated Sludge. II. On the Causative Organism," *Ibid.*, 6, 1041 (Nov., 1934).
16. C. C. Ruchhoff and J. H. Watkins, "Bacteriological Isolation and Study of the Filamentous Organism in the Activated Sludge of the Des Plaines River Sewage Treatment Works," *Ibid.*, 1, 52 (Oct., 1928).
17. C. T. Butterfield, "Studies of Sewage Purification. II. A Zoogaea Forming Bacterium Isolated from Activated Sludge," *Pub. Health Reports*, 50, 671 (May 17, 1935), *Treas. Dept. Reprint No. 1686*.
18. Max Levine and L. Soppeland, "Proteolysis by Bacteria from Creamery Wastes," *Bulletin 82, Eng. Exp. Sta. Iowa State College* (1926).
19. W. R. Woodbridge and A. F. E. Standfast, *Biochem. Jour.*, 30, 156 (1936).
20. H. Henckelien, "Carbon Dioxide Production in Mixtures of Sewage and Activated Sludge," *This Jour.*, 8, 210 (March, 1936).
21. H. Henckelien and R. S. Ingola, "Studies on the Clarification and Oxidation Stages of Activated Sludge," *Ibid.*, 9, 717 (Sept., 1937).
22. H. Henckelien, "Dissolved Oxygen," *Waterworks and Sew.*, 85, 715 (July, 1938).
23. Geo. C. Whipple, "The Microscopy of Drinking Water," 3rd Edition, p. 262.
24. E. A. Reine, "Operation of Typical Sewage Disposal Plants in California and Comparison with Results Obtained Elsewhere," *Calif. Sew. Wks. Jour.*, 4, 48 (1931).
25. E. A. Reine, "Sewage Analyses and What They Tell the Operator," *Ibid.*, 5, 72 (1932-33).
26. E. J. Theriault and P. D. McNamee, "Experimental Studies of Natural Purification in Polluted Waters. IX. Nitrification in Sewage Mixtures," *Pub. Health Reports*, 49, 1169 (Oct. 5, 1934), *Treas. Dept. Reprint No. 1651*.
27. T. Chujo, "Adjustment of pH Value of Sewage by Means of Carbon Dioxide," *This Jour.*, 9, 750 (Sept., 1937).
28. E. P. Eldridge, W. L. Mallman and G. H. Robinson, "The Utilization of Carbohydrates and Proteins by Activated Sludge Organisms," *Mich. Eng. Exp. Sta. Bulletin* 60, (Nov., 1934); abstract *This Jour.*, 7, 766 (July, 1935).

Industrial Wastes

THE PHENOLIC WASTE TREATMENT PLANT OF THE DOW CHEMICAL COMPANY

BY IVAN F. HARLOW, THOMAS J. POWERS AND RALPH B. EHLEERS
Superintendent in Charge of Waste Disposal, Sanitary Engineer and Civil Engineer

The Dow Chemical Company, with its main plant located on the Tittabawassee River at Midland, Michigan, produces over 250 products. Situated on a 2,000-acre site, plant buildings now number over 300, in which are manufactured various industrial chemicals, intermediates, organic solvents, pharmaceuticals, aromatics, insecticides, dyes, and Dowmetal. Starting in 1897 to produce bromine and salt from a brine pumped out of a formation 1,200 ft. below the district, the industry has branched out, employing each new by-product to make a marketable product. The Company now has the largest and most modern phenol manufacturing plant in the world, and has become a major producer of the country's supply of aspirin, other salicylates, bromine, epsom salts, and magnesium metal.

The Tittabawassee River, source of the plant water, originates to the west and north of Midland. The flow of the river is regulated by hydroelectric plants upstream and average daily flows reach minimums as low as 150 cu. ft. per second during dry summer months. At such times the plant pumps practically the entire river flow. After receiving plant wastes, the river flows southeast to Saginaw where it is joined by other tributaries to become the Saginaw River. This river then flows north through Bay City to Saginaw Bay and Lake Huron. The city of Saginaw takes its raw water supply directly from the Saginaw River. The city of Bay City pumps water from Saginaw Bay at a point just a few miles west of the Saginaw River mouth, making it possible for easterly winds to move river water to the intake.

POLLUTION CONTROL HISTORY

As the Company grew, correctional steps were taken to keep pace with the increasing volumes of waste water. The manufacture of phenol from benzol and the production of salicylates and a host of phenolic compounds, added wastes of a nature that could be objectionable in water in very minute amounts. The Company began early to pond its wastes. Waste brines were stored in huge ponds to be released during periods of high dilution. Process waters carrying precipitates and other suspended matter were ponded for settlement. Concentrated wastes containing soluble organic compounds were pumped to storage ponds before being carefully released during warm weather. By 1931, the Company had in operation over 600 acres of

diked ponds, three separate sewer systems, outlet structures and pumping equipment, all of which represented an investment of well over \$1,000,000.

The present plant for treatment of phenolic wastes is the result of years of research. Starting in 1927, the Company has investigated practically all of the known methods of recovering or destroying phenolic compounds in dilute solutions. The mixed wastes, containing so many phenolic compounds, made recovery by extraction of useful products very expensive. Adsorption methods, while effective, were also thought to be too expensive. Biochemical methods showed considerable promise and an experimental plant employing the German "Tank Filter" was operated from September, 1935, to June, 1937. Trickling filters of various design and depth were also used in conjunction with the Emscher filters.

Comprehensive surveys of downstream river conditions over a period of years had clearly demonstrated that the critical period for phenolic pollution was during the months when river temperatures were less than 15° C. Strong phenolic waste was held in storage ponds during these months and only weak wastes reached the river. The problem, then, was to segregate all weak wastes from each phenolic product plant and to attempt to treat these diluted wastes. Further investigation of biochemical oxidation processes indicated that bacteria of natural soil origin were predominant in the biological units in which phenol was destroyed. These studies led to the experimental use of river water instead of sewage as a diluent for strong wastes and subsequently indicated that treatment of strong wastes diluted by weak wastes was possible.

Having established practical operating rates and acceptable effluents in experimental units, design of a full-scale plant was undertaken. The trickling filter was chosen as the biological unit because it was believed to be the simplest to design, construct, and operate. Past experience in sewage treatment has shown the trickling filter to be rugged in operation and resistant to variable demands or toxic substances. Extensive studies of filter media indicated that blast-furnace slag would be the best material for expected conditions from the standpoints of weathering, surface roughness, and chemical stability.

GENERAL DESIGN FEATURES

The actual design of the plant was begun in February, 1937. The general design features were based on the conclusions drawn from the data collected during the operation of the experimental plant. It was fully appreciated that this plant would serve as a large-scale experimental plant, and so the functioning elements were made as flexible in their operation as possible. Those parts of the plant which could easily be duplicated, or enlarged were reduced in capacity somewhat in the present installation. Other parts of the plant, which could not

easily be increased in capacity later, were actually made oversize in the present installation. Thus, the elements of the present plant appear, at first glance, to be a collection of structures, each designed on

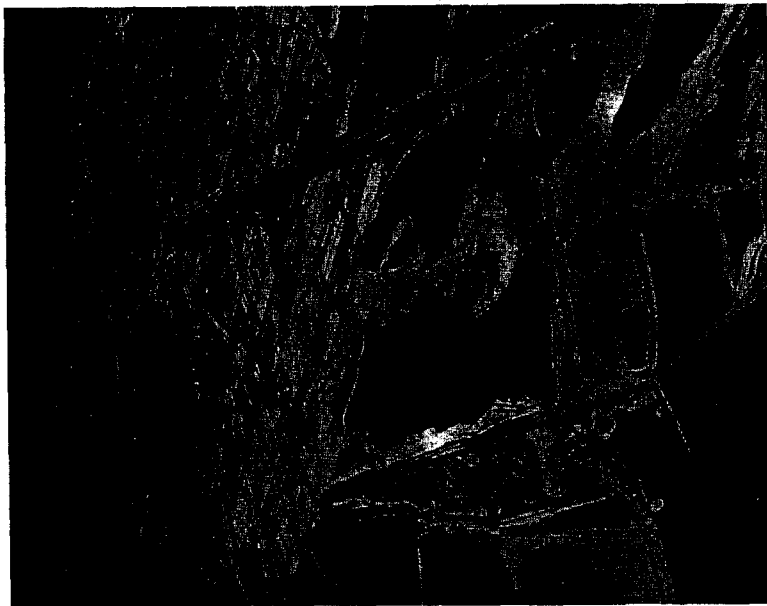


FIG. 1.—Aerial view of the phenolic waste treatment plant of the Dow Chemical Company.
(Courtesy Fairchild Aerial Surveys, Inc.)

a different basis of flow or capacity; but the plant as a whole actually is one which is quite flexible as to rate of present operation, and its capacity can be increased easily by adding duplicate or new elements.

The principal elements of the present plant (Fig. 1) are:

1. *The waste sewer systems*, collecting and delivering the wastes to a
2. *Pumping station*, including a small control laboratory and the pH control equipment, where the weak and strong wastes are mixed, conditioned and pumped through a
3. *36-in. steel pumping main*, in which the wastes are metered through an orifice plate, and delivered to a
4. *Settling tank*, containing a clarifier mechanism. The settled wastes flow by gravity through a 30-in. steel main with 16-in. cast iron branches to the two
5. *Trickling filters*, each of which has a power-driven rotary distributor. The effluent from the filters flows by gravity from center collection galleries through a
6. *30-in. and 36-in. outfall sewer* to the
7. *Outlet gate structure*, where the plant effluent is carried a short distance in an open ditch and discharged into
8. *Effluent ponds*, which have an area of 38 acres and from which the treated wastes are discharged into the Tittabawassee River.

WASTE SEWER SYSTEMS

There are two sewer systems used to collect and deliver the wastes to the treatment plant. The first, which we shall call the strong wastes system, was in use prior to the construction of the treatment plant. It received the strong acid wastes and discharged them into one of the waste ponds. This system and its pond were incorporated in the general waste treatment program. The new work involved building about 325 ft. of 10-in. cast iron pipe from the pond to the new pumping station building.

The other sewer system, built to collect the weak wastes, involved much more work. As a backbone for this system, it was decided to use one of the other two existing sewer systems. In order to do this, many sewer changes were necessary. These changes involved cutting off sewer outlets from buildings whose wastes were not to be treated, and providing new outlets. All buildings whose wastes were to be treated had to be connected into the weak waste system. Inasmuch as all outside yard drainage around the buildings had to be collected, these sewers were designed as storm sewers, and are quite large, ranging in diameter from 10 to 24 inches. About 8 per cent of the total cost of the project was spent on these sewer changes.

This revamped sewer system discharged into a pond approximately 3,300 ft. north of the treatment plant site. At the outlet, the system consisted of a 24-in. sewer and a 36-in. relief sewer, each of which carried dry-weather flow. The design storm-flow capacity of these two sewers is 54 cu. ft. per second or about 36 million gallons per day (M.G.D.). The treatment plant program had to include provisions for carrying at least the dry-weather flow of these sewers to the plant site.

A 42-in. concrete trunk sewer, 3,300 ft. long, was built to carry the wastes from the outlet of the weak wastes sewer system to the pumping station. This sewer has a design capacity of 22 M.G.D. A steel sheet piling overflow weir was provided at the junction of the 42-in. and the 24-in. and 36-in. sewers to divert the excess storm flows into the effluent pond. This 42-in. sewer, with its appurtenant structures, represents about 11 per cent of the total cost of the project.

PUMPING STATION

The weak wastes are discharged from the 42-in. sewer into a small earth-bank pool at the pumping station. (Fig. 2) A steel sheet piling

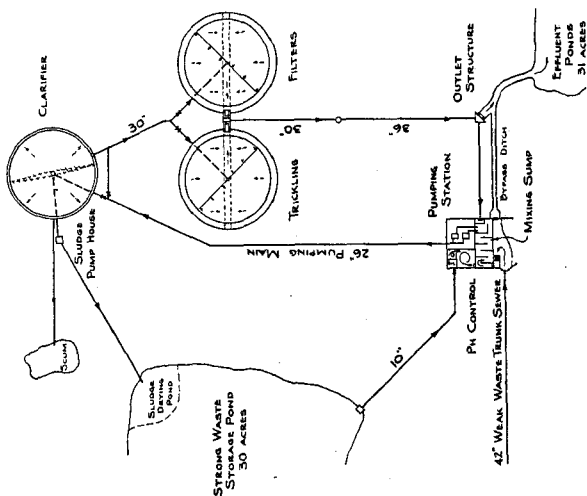


Fig. 2.—Flow diagram of phenolic waste treatment plant.

cut-off wall and overflow weir separates this pool from the open ditch into which the plant effluent is later discharged. One side of this pool is bounded by an open concrete tank which serves as a mixing tank and pump suction well. The weak wastes enter this tank through a coarse bar screen and a 42-in. square sluice gate. The bar screen is manually raked.

The mixing tank (Fig. 3) is provided with around-the-end type wood baffles which form a series of passes through which the wastes are directed to the pump suction pipes. In the first pass, directly opposite the weak waste entrance port, the strong wastes are also discharged through a 12-in. valved port from a conditioning tank inside the pumping station structure.

The strong wastes are first discharged by gravity, from the 10-in. pipe line previously described, through a throttling valve into a weir box inside the pumping station proper. The flow is measured through a hardwood V-notch weir, and discharged into a concrete mixing tank equipped with a turbine mixer. Hydrated lime is added at this point, from a gravimetric belt-type feeder, for pH control. From the mixing



FIG. 3.—Mixing chamber, with strong waste entering through 12-inch port.

tank the strong wastes pass through a concrete conditioning tank provided with revolving paddle agitation, and thence into the baffled mixing tank, as described above.

The mixed wastes are pumped from the suction well to the settling tank by means of motor-driven centrifugal pumps. The present installation includes one 9,000 g.p.m. and one 5,600 g.p.m. pump, driven by 125 h.p. and 75 h.p. motors, respectively, operated at 690 r.p.m. on 2,300 volt, 60 cycle, 3 phase power. Automatic low-water shut-off control for these pumps is provided by means of induction relays, and electrodes submerged in the suction well. The pumps are started by manual control, with pump and suction line priming service supplied by a manually-controlled vacuum pump.

Inasmuch as the treatment plant is located more than three-fourths of a mile from any of the Company's service lines, pressure water for cleaning and flushing purposes is supplied by means of a 160 g.p.m., 3,500 r.p.m. pump with a 10 h.p., 440 volt motor. The feed for this pump is taken from the treated plant effluent. Water for the control laboratory, drinking purposes, and sanitary service, is supplied by a

small automatic piston pump from a deep well at the treatment plant site.

The pumping station substructure is of reinforced concrete with brick superstructure, steel sash, and cement tile roof deck covered with composition roofing.

The cost of the pumping station, including all equipment, piping, and valves, amounted to about 19 per cent of the total project cost.

26-INCH PUMPING MAIN

The two waste pumps discharge into a 26-in. steel pipe line, which carries the wastes either to the settling tank, or through a 26-in. steel by-pass line to the settling tank effluent line. The pumping main is approximately 850 ft. long, including about 72 ft. of 30-in. cast iron pipe laid beneath the floor slab of the settling tank. The balance of the main is 26-in. outside diameter, by $\frac{3}{8}$ in. thick, dipped-and wrapped welded steel pipe. The pipe was fabricated in 30-ft. lengths, and all field joints were shielded-and welded. One expansion joint was provided, using a special coupling. A $\frac{1}{4}$ -in. steel orifice plate, with bolted flanges provided with spreader bolts, was installed in the line at a point about 40 ft. from the pumping station.

The line is laid on a slight grade, pitching back toward the pumping station. A 10-in. blow-off and drain line at the low point permits draining the main and about one-half the volume of the settling tank into the same pond which receives the plant effluent. A 4-inch welded steel dipped-and-wrapped pressure water line was laid in the same trench with the waste pumping main; and it also can be drained into the effluent pond. The cost of these pipe lines represents 6 per cent of the total costs.

SETTLING TANK

The waste pumping main discharges at the center of the settling tank (Fig. 4). This tank is of reinforced concrete construction with

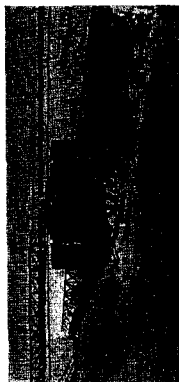


FIG. 4.—View of empty clarifier.

an effluent launder around the entire periphery, poured monolithically with the tank wall. The tank has an inside diameter of 140 ft., has an 8-ft. side water depth, and the usual 1 to 12 bottom slope. The normal water surface is 28.5 ft. above the average operating water level at the

waste pump suction pipes. A 60-degree, V-notch steel plate outlet weir is provided around the entire periphery of the tank. Surface scum and oil is prevented from overflowing this weir by means of a steel baffle plate partially submerged about 8 in. inside the weir, and supported by means of inverted V-shaped hangers welded to a steel angle ring anchored to the top of the tank wall. The weir plate is also bolted to this ring.

A clarifier mechanism, provided with skimming arms, is installed in the settling tank. Surface skimmings are discharged by gravity into a nearby swale, controlled by a manually-operated quick-opening ball valve. Settled sludge is removed by a piston pump and discharged into one of the waste ponds adjacent to the plant site. The design capacity of the settling tank was based on a 1-hour detention period for a 20 M.G.D. flow. Approximately 18 per cent of the total cost of the project was expended on the settling tank and its appurtenances.

TRICKLING FILTERS

The experimental work which led to the selection of the trickling filter has been mentioned. The next item of consequence was the selection of the type of filter media and the type of bottom underdrains. The data obtained from the experimental work, as well as the published data on filter design and operation, emphasized the importance of circulation of air through the filter bed.

Inspection trips were made to several municipal waste disposal plants where trickling filters were operating or were being built. Published data on the operating results, construction problems, and design features of trickling filters were studied, including the report of the committee of the American Society of Civil Engineers on "Filtering Materials." Tests were run, based on the above report, on coke, crushed blast furnace slag from six different sources, dolomitic limestone from two quarries, and limestone from three quarries. Inasmuch as shipment by boat was possible, with unloading facilities at the Company's own dock, the shipping cost was an item of ranking importance. Careful analysis of durability, size, shape and uniformity of crushed particles; surface contour of crushed media with relation to bacteria growth and the sloughing of this growth; ease and cost of handling and placing, the cost of the material, led to the selection of crushed blast furnace slag shipped in by rail.

The slag purchased was specified to have an average screen analysis as follows:

Screen Size, Inches	Percentage Passing
4	100
3½	95
3	60
2½	20
2	8
1½	Not more than 3

In order to hold the percentage of "fines" to a minimum, it was decided to re-screen the slag at the site as the last operation before placing it on the filters. It also appeared advisable to remove all pieces showing excessive iron.

Inasmuch as early completion was also deemed essential, endless belt conveyors were selected for unloading and placing the slag. A small hopper was built under an existing car siding approximately 800 ft. from the filters. A 75-ft. stationary conveyor, with reciprocating feeder, was purchased and erected. This conveyor discharged into a reconditioned gyrating screen. The screen discharged the fines directly into a truck, and the screen slag was discharged into a steel

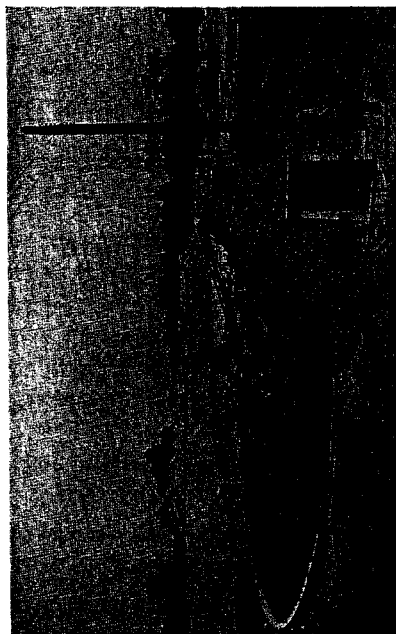


FIG. 5.—Trickling filter under construction.

hopper having a capacity of about 4 cu. yds. This was a salvage hopper on hand, which was reconditioned and fitted with a hand-operated under-cut bin gate. One and one-half yard trucks were loaded by gravity from this hopper. At the filters, a 25-ft. portable conveyor was used, with a special low hopper on the feed end, so that the trucks could dump directly onto the belt (Fig. 5). The entire handling setup was designed to handle 500 tons of slag in an 8-hour day. The final records show that 246 cars containing 14,113 tons of slag were unloaded, screened and placed on the filters at an average rate of 69 tons per hour. Of the total weight handled, 13,457 tons were actually placed on the filters; 455 tons, or 3.2 per cent, were screened out through the 1½-inch screen; and 201 tons, or 1.4 per cent, were removed as pieces containing excessive iron. The high-iron pieces were hand-picked off the stationary conveyor as the slag was elevated to

the screen. The screenings and iron culls were stock-piled, to be used later as road ballast, special concrete aggregate and other uses by the Company, so were not a total loss.

The two filters (Fig. 6) are somewhat unusual in design. The topography of the site was such that the filter bottoms were built on approximately the natural ground surface. The maximum cut was about 4 ft. and the maximum fill was about 1 foot. The 4-in. concrete slab bottom was laid on this prepared grade. Instead of pouring concrete walls to retain the slag media, the side slope of the slag itself is used as the retaining wall. This was done to reduce costs, and not in the hope that any material benefits in ventilation could be obtained. A

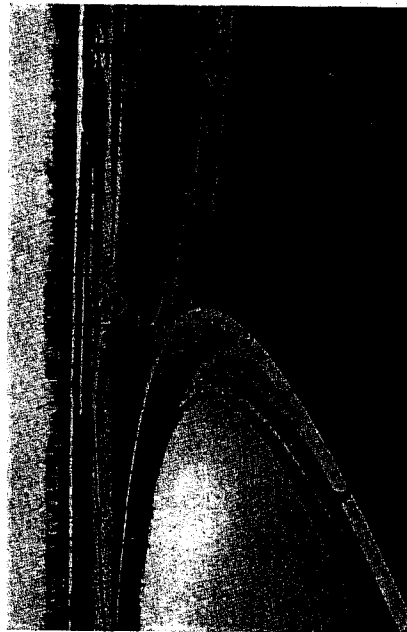


FIG. 6.—View of clarifier and filters.

45-degree side slope was used on the slag bed, and although this slope stands satisfactorily, the construction work indicated that a slightly flatter slope would be easier and faster to build. The filters have a diameter of 142 ft. at the top and 162 ft. at the bottom. The slag is 10.25 ft. deep at each side of the center gallery, with an average depth of about 9.75 ft. outside the gallery area, and the slag depth over the gallery roof varies uniformly from 5 to 7 feet.

Filter bottom tile are laid in mortar over the bottom slab to give 100 per cent coverage under the wetted area. The drains formed by these blocks slope toward the center gallery, which was built as a concrete rectangular box 6 ft. high and 4 ft. 8 in. inside. (Fig. 7) The ends of the gallery are open. The walkway space is 2 ft. wide, being separated from the collecting gutters on each side by a low concrete wall.

Filter blocks are also laid on the roof of the gallery. Effluent from these drains is discharged into the gallery gutters below. It is possible, therefore, to stand in the gallery, sight through any under-drain, and see daylight at the other end. Each drain can also be individually flushed. The longest drain is about 76 ft. long and the shortest 35 ft. long. It is believed that these filters have the very maximum possibilities for natural ventilation, due to these unusual construction features.

The filter influent is distributed over the beds through power-driven rotary distributors. Each distributor is 141 ft. in diameter and was designed for an average flow of 2.67 M.G.D. while rotating at $\frac{3}{4}$ r.p.m.; it serves an area of 15,800 square feet. Power drive was selected be-

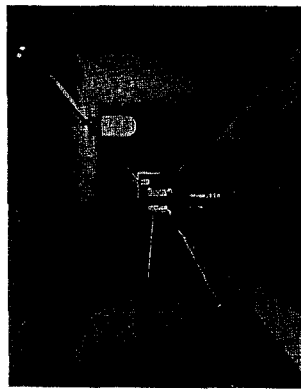


FIG. 7.—Filter gallery, showing drainage.

cause of the anticipated variation in rates of flow. The effluent is carried in the center gallery gutters to a manhole located on the common center line of the galleries and midway between the filters. The outfall sewer picks up the treated wastes at this manhole.

The filters complete cost approximately 30 per cent of the total costs.

OUTFALL SEWER AND OUTLET GATE STRUCTURE

The outfall sewer is 30-in. double-strength vitrified tile at its upper end, and is increased to 36-in. size at a manhole into which possible future structures may discharge. The sewer is approximately 610 ft. long. A sluice gate is provided at the outlet structure so that the sewer may be segregated from the open ditch and pond into which it discharges. A sewer connection from the outlet gate structure to the waste pump suction will permit pumping the entire effluent system dry. The outfall sewer and gate structure represent 3 per cent of the total cost.

SPECIAL CONTROL FEATURES

An operator is on duty at the plant only eight hours a day. The plant is visited by a control chemist every two hours of the other two shifts. In order to have a continuous record of operation, recording gages were used. Three liquid level gages, with 7-day charts, indicate and record the water level at the strong wastes and weak wastes in-fluents at the pumping station, and the treated plant effluent. An indicating, recording and integrating flowmeter, also with a 7-day chart, records the flow through the orifice in the 26-in. pumping main. Mention has already been made of the automatic shut-off control for the large waste pumps.

The experimental work indicated the necessity for temperature and pH control, so recording meters were installed as a guide for this control. A Wheatstone-bridge type multipoint temperature recorder, calibrated for use with nickel resistance thermometers, records the temperature of flow at four key points in the plant. All of these four readings are recorded on one 30-day strip chart. In a similar manner, readings from three key points for pH control are recorded on a three-point potentiometer type hydrogen-ion recorder with a 30-day strip chart. All of the indicating and recording gages are dash-mounted on a steel panel in the control laboratory at the pumping station. These control features amounted to 1 per cent of the total cost.

All of the structural design work for the treatment plant was done by the Company's engineering department; and, except the earthwork for the preparation of the site and the installation of the 42-in. sewer, the construction work was done by the Company's construction department.

OPERATING RESULTS

The plant was placed in operation the last week of October, 1937. During November and December of that year difficulties were encountered in obtaining sufficient heat in weak wastes. An open ditch was being used to convey weak wastes to the pumping station and this resulted in considerable heat loss. The 42-in. trunk sewer was completed the latter part of December. Many changes in the use of condenser water at several production plants and use of the trunk sewer increased weak waste temperatures to an average of 70.5° F. for the month of January, 1938. Continuous survey of the weak waste sewer system was necessary to eliminate fluctuating conditions. On the whole, very little trouble was encountered that might not be expected in placing any new plant into operation.

The operating data are summarized in Table I. By "gross" phenol is meant the bromine demand expressed as p.p.m. phenol. Many compounds other than phenol will brominate. The test is simple to perform and gives a ready indication of plant efficiency. All "net" phenol figures are from analyses after double-distillation, first from acid then from calcium carbonate. Phenol in excess of 20 p.p.m. is

TABLE Ia.—The Dow Chemical Company Phenolic Waste Treatment Plant
Monthly Averages of Operating Data

		Flows—Million Gallons per Day											
		1937						1938					
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
Weak waste by-passed to effluent pond	1.78	0.48	0.01	1.00	0.10	0.10	0.19	0.57	0.20	0.62	1.72	0.86	Weak waste
Weak waste to plant	6.22	6.10	6.24	6.09	8.28	8.88	11.42	10.84	10.97	11.50	9.36	0.28	Mixed waste
Strong waste to plant	0.06	0.11	0.20	0.17	0.52	0.84	1.08	0.87	0.83	0.83	0.87	0.28	Settled waste
Effluent recycled	0.22	0	0.18	0	0	1.01	0.87	0.80	0.83	0.83	0.87	0.28	Filter effluent
Total to filters	6.49	6.21	6.37	6.26	8.80	10.83	12.87	12.32	12.10	12.20	10.24	0.60	Pond effluent
Effluent pond	8.05	6.64	6.45	7.26	8.90	10.01	13.07	11.72	11.89	13.55	10.50	0.86	Air
Temperatures—Degrees Fahrenheit													
Weak waste	61	62	70	65	71	73	78	79	80	87	90	78	Weak waste
Mixed waste	61	62	69	63	69	73	78	79	80	87	90	78	Mixed waste
Settled waste	—	59	66	61	67	72	78	85	86	88	89	77	Settled waste
Filter effluent	55	56	59	56	63	68	76	83	83	86	87	76	Filter effluent
Pond effluent	43	37	37	38	46	52	62	66	68	71	76	63	Pond effluent
Air	38	25	22	28	38	47	58	68	68	73	74	59	Air

Table II.—Monthly Averages											
Analytical Data—Gross phenol—P.P.M.											
Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
7	11	8	7	8	6	3	5	3	3	4	Weak waste.
369	431	453	380	359	305	409	356	342	458	458	Mixed waste.
13	17	20	17	34	36	24	24	8	11	14	Settled waste.
15	17	22	18	31	35	24	24	7	9	13	Filter effluent.
6	6	5	5	8	8	6	5	2	2	2	Pond effluent.
5	6	4	9	5	4	4	4	2	2	2	
Net phenol (by Gibbs)—P.P.M.											
4.1	5.3	3.6	3.8	3.9	3.1	2.1	1.5	1.1	0.8	1.3	Weak waste.
207	242	283	229	221	190	174	227	169	165	273	Strong waste.
5.8	9.7	11.0	10.1	18.1	20.1	17.5	13.4	3.3	4.2	8.3	Mixed waste.
—	8.8	11.0	10.5	18.2	20.1	18.0	14.4	3.3	3.8	7.9	Settled waste.
1.3	1.3	1.0	2.0	2.2	2.3	1.6	0.88	0.10	0.08	0.18	Filter effluent.
1.7	0.73	0.31	1.45	0.92	0.11	0.05	0.02	0.02	0.02	0.01	Pond effluent.
5-Day B.O.D.—P.P.M.											
703	759	846	968	745	635	479	656	634	538	820	Strong waste.
34	64	68	98	98	90	68	68	34	30	49	Mixed waste.
34	56	66	68	98	63	60	60	32	26	48	Settled waste.
21	16	19	18	19	17	20	20	7	4	8	Filter effluent.
19	16	16	17	14	10	9	8	7	4	4	Pond effluent.
Total Cl as NaCl—P.P.M.											
657	1310	1560	1112	1315	1680	1516	1160	782	761	789	Filter effluent.
Note: Approximate pH of wastes is as follows: Strong waste = 1.8, Weak waste = 7.0, Mixed waste = 6.5, Filter effluent = 7.5.											

Table I.—Monthly Averages

Quantitative Data—Phenol (by Gibbs)—Pounds per day.											
Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
1937	1938										
373	526	601	580	1403	1802	1937	1478	338	438	716	Total Phenol to System.
314	507	602	548	1400	1817	1932	1480	333	427	708	Mixed waste.
314	507	602	548	1328	1817	1932	1480	333	427	708	Settled waste.
70	67	56	104	161	208	172	70	10	8	15	Filter effluent.
2	0	1	0	20	5	3	1	0	0	1	Recycle.
61	19	0	32	3	5	10	6	6	11	9	Weak waste by-passed.
129	86	54	136	164	193	177	15	19	23	23	Pond influent.
114	40	17	88	68	9	9	2	2	2	0.9	Pond effluent.
B.O.D.—Pounds per day.											
1840	2850	3560	3550	6830	8850	9660	6980	3430	3055	4180	Mixed waste.
1840	2850	3560	3550	6830	8850	9660	6980	3430	3055	4180	Settled waste.
1187	828	1150	783	1390	1625	1825	2055	707	407	684	Filter effluent.
1408	830	860	1080	1040	835	981	782	694	452	350	Pond effluent.
Filter Rates.											
9.0	8.3	9.1	8.7	12.2	16.2	17.9	17.0	16.8	16.9	15.6	M.G.A.D.
0.81	1.46	1.81	1.47	3.86	5.33	5.82	4.67	1.07	1.25	2.18	Lbs. of Phenol removed per 1000 cu. ft. per day.
2.33	6.68	7.98	9.16	13.00	19.45	16.35	13.60	8.34	7.44	9.90	Lbs. of B.O.D. removed per 1000 cu. ft. per day.
Phenol Disposal—Percent of Total of System.											
0	0	0	0	5.1	0	0	0	0	0	4.6	Charter.
65.4	82.7	91.0	76.6	83.2	90.8	87	95.4	95.6	86.5	92.2	Effluent ponds.
69.4	82.4	87.1	84.9	95.1	99.5	99.5	99.9	99.4	99.5	99.9	Total.

The results of analyses of samples taken at various filter depths are shown in Table II.

TABLE II.—Phenol Remaining at Various Filter Depths

Average Rate = 15.5 M.G.A.D. Average Effluent Temp. = 75° F.	
Phenol by Gibbs Method	
Filter Top.....	12.2 p.p.m.
5.5-ft. Depth.....	1.9 p.p.m.
6.5-ft. Depth.....	1.3 p.p.m.
9.75-ft. Depth.....	0.41 p.p.m.

From these average analyses, it can be seen that the last 3.25 feet produce an effluent that is 68.5 per cent better than the effluent from the first 6.5 feet. Each foot of filter is shown to remove about 30 per cent of the load applied to it.

Of special interest may be the fact that there is no filter fly problem at this plant. The construction features of the gallery and side slope make an ideal breeding place for filter flies, but apparently there is sufficient para and ortho-dichlorobenzene present to prevent development.

The effectiveness of the effluent storage ponds is clearly shown in Table I. An additional 17-acre pond was added to the 21-acre pond on May 18, 1938. It is estimated that these ponds provide about 48 hours detention time at a flow of 10 M.G.D. If the ponds can not oxidize the sloughed material from the filters as fast as it is accumulated and become septic, it is intended to lower the pond levels and allow this sludge to dry to a cake which can be scraped or floated off.

It will be noted that some effluent has been recirculated. In the experimental plant it was found that recirculated effluent seeded the influent to such an extent that as much as 50 per cent phenol reduction was experienced in the settling tank. Loss of heat does not permit recirculation during the colder months and effluent was used during the warmer months to make up weekend flows to a constant pumpage rate. The effect of recirculation has not been clearly indicated in the full-scale plant.

In conclusion it may be stated that the plant described has more than accomplished the purpose for which it was designed.

determined by bromination of distillate. On lesser amounts, the determination is made by the Gibbs colorimetric method. Phenol, chlorophenols and cresol, together with a number of other ring compounds with a free hydroxyl group will show a color reaction in this test. Samples for analyses are taken every two hours and composited for the twenty-four-hour periods. Additional spot samples are taken every morning to check composite analyses. B.O.D. results are on spot samples taken three times a week. Dilution water is made by aerating distilled water, adding 300 p.p.m. NaHCO_3 , and seeding with river water instead of sewage.

The clarifier, while not performing the work comparable to a sewage plant primary settling tank, has served its purpose very well. When lime is added to strong wastes to bring pH above 6.0, an iron hydrate floc results; during such times, the clarifier removes many inorganic solids and such organic matter as is held in suspension or emulsion. As a general rule, sludge is pumped but once a day and does not usually run over 1000 gallons per day. This sludge is drained to a small shallow pond adjacent to the strong waste storage pond where it is dewatered by evaporation and drainage through a sand dike. Since sludge is such a minor problem, analyses for suspended solids are not made. An average of 8.4 per cent of the B.O.D. is removed by the clarifier. There is very little, if any, phenol removal in this unit. The clarifier serves to iron out changes by virtue of its detention time and it prevents short circuiting.

The filters have received many "shocks" and in their early growth days were rendered almost completely sterile several times by acids, caustic, and free chlorine. Sewer changes have eliminated many of these dangers, but there still exist occasional pH and organic load changes that might spell disaster for a less rugged process. These fluctuations have been ironed out and oxidized in the effluent ponds. The operation of this plant has shown that a well-seeded filter will withstand sudden pH and toxic compound "shocks" with remarkable ability and will quickly recover to former efficiency.

The filters slough continuously and have never shown any indication to pool except in a few very small areas where fine aggregate accumulated on the surface during construction.

It might well be asked why a ten-foot filter was built when sewage treatment practice leans toward beds of less depth. The purpose of this plant from the outset was to produce the best effluent possible at least cost. In order to save cost on filter area a relative high rate of surface application was found to be possible, provided sufficient filter depth was available to attain the effluent thought to be necessary. Greatly increased removals of phenol per cubic foot of filter body can readily be attained by high rates of application on shallower beds, but the quality of the effluent deteriorates. It must be remembered that, unlike domestic sewage, practically all of the organic matter contained in these wastes is in true solution.