DESCRIPTION OF

# Milwaukee's Activated Sludge Sewage Disposal Project

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of the
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# Milwaukee's Activated Sludge Sewage Disposal Project

## HISTORICAL

Milwaukee, Wisconsin, population 500,000, situated on the western shore of Lake Michigan at the junction of the Milwaukee, Menomonee and Kinnickinnic Rivers, has been advised since 1879 to take steps to prevent the sewage laden rivers and inner harbor from discharging their ever increasing filth into Lake Michigan, which is the source of the city's water supply and is used extensively during the summer months for bathing. In 1913 the Legislature of Wisconsin passed an act authorizing the City of Milwaukee to create a Sewerage Commission consisting of five members. Thereupon the Common Council passed a resolution declaring it was necessary to provide Sewage Disposal Works and the Mayor immediately appointed five citizens who qualified and the Commission was then ready to function. By 1914 T. Chalkley Hatton, who had been selected by the Commission as its Chief Engineer, had perfected his organization and had begun the construction of a Sewage Disposal Testing Station on Jones Island for the study of processes of sewage disposal suited to Milwaukee's conditions. In 1915 preliminary laboratory studies were made on the newly discovered activated sludge process. These tests were so promising that larger tanks were immediately constructed and the new process was intensively studied on a practical working scale. By the end of 1917 the Commission, upon recommendation of its Chief Engineer, had decided informally that this process was best adapted to Milwaukee's needs but, before taking final action on such an important matter involving the expenditure of many millions, it was agreed to run the activated sludge demonstration plant at least another year. In fact the plant was run practically continuously for nearly two years and on December 31, 1919, the Commission formally adopted the process described in the following pages.

In July, 1921, the Legislature passed a second act creating the Metropolitan Sewerage Commission consisting of three members to project, plan and construct in the County of Milwaukee, outside the city limits, first class main sewers to connect with the intercepting sewer system of the City of Milwaukee. This means that all sanitary and industrial wastes created in the drainage district of which Milwaukee is a part, will be received and treated at the central disposal plant on Jones Island. All work in connection with the Metropolitan or outlying sewers is being done by the staff of the Milwaukee Sewerage Commission. When the disposal plant goes into operation an area of 96,800 acres will be served with a population of approximately 575,000. The dry weather flow of sanitary sewage and industrial wastes will be about 75,000,000 gallons daily, which will increase as the population of the district increases.

## DESCRIPTION OF THE ACTIVATED SLUDGE PROCESS

The sanitary sewage and trade wastes originating in Milwaukee County will be brought to the disposal plant on Jones Island through a comprehensive system of intercepting sewers terminating in four siphons (2 low and 2 high level), but under the harbor entrance 75 ft. below water level. The raw sewage, after passing through bar screens to remove the large materials, flows through grit chambers where the mineral matter settles out. From the grit chambers the sewage passes through revolving fine drum screens, the effluent from which passes into an aerated conduit where it is mixed with 15-20% by volume of "Activated Sludge" returned from the sedimentation tanks. The sewage and sludge called "Mixed Liquor" is then distributed to the aeration tanks in the bottom of which are placed filtros plates, each 1 ft. square, through which air at 8 to 10 lbs. pressure is forced so as to produce a continuous stream of tiny bubbles. After 6 hours contact with air and returned sludge, about 95% of the organic matter in the raw sewage is precipitated and a remarkable purification is effected. The "Mixed Liquor" then passes into sedimentation tanks equipped with Dorr Thickeners where, after approximately 30 minutes settling, the granular precipitate settles to the bottom and the purified effluent flows out at the top and is discharged into a conduit emptying into the lake. In the brief time of 6 to 7 hours the raw sewage has undergone such purification that the liquor emptying into the lake is as clear and colorless as drinking water and will show an average reduction of 98% bacteria and 97% suspended matter. Sewage will enter the plant and purified effluent will leave it continuously; furthermore the reduction of sludge to dry fertilizer material which will now be taken up, will also go on uninterruptedly.

After sedimentation, the activated sludge has been brought down to about 98% moisture content. After this sludge is withdrawn from the bottom of the sedimentation tanks about 90% is returned to and mixed with the incoming raw sewage, the remainder (about 15,000 gals. per million gals. sewage) being pumped to the filter house where the moisture content is further reduced to 80% or less—whereby the greatest bulk of the water is removed. This dewatering is accomplished by means of Oliver Continuous Vacuum Filters which produce a thin cake in ribbon-like form. The excess water which passes through the filters is practically sterile due to the heat and acid treatment the sludge gets and is returned to the inner harbor. The sludge cake, while hot, is conveyed to the dryer house into direct-indirect-heat continuous dryers in which the remaining water is evaporated off, dry fertilizer material coming out at the other end. After screening and grinding, the sludge will be in the form of an ammonia tankage ready for mixing with potash and phosphate into a complete fertilizer. It is estimated that 1¼ tons of dry tankage will be obtained from every million gallons of sewage; hence an initial production of 100 tons daily is expected, which will increase yearly as the population increases.

Following is a typical analysis of the ammonia base fertilizer which the Milwaukee plant will produce:

| | |
|---|---|
| Moisture | 5.75% |
| Total Phosphoric Acid | 2.34 |
| Total Nitrogen as Ammonia | 7.32 |

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| | |
|---|---|
| Water Insoluble Nitrogen as Ammonia | 6.65 |
| Water Soluble Nitrogen as Ammonia | 0.67 |
| Active Water Insoluble Organic Nitrogen as Ammonia | 3.94 |
| Total Available Ammonia | 4.61 |
| Per cent. Total Availability of Ammonia | 62.97 |

## HYPOTHETICAL ANALYSIS
### OF THE COMBINED SEWAGE AND TRADE WASTES TO BE RECEIVED AND TREATED AT THE DISPOSAL PLANT

| | |
|---|---|
| Total Solids | 950.0 |
| Suspended Solids | 250.0 |
| Organic Nitrogen as Ammonia | 18.0 |
| Oxygen Consumed in one-half hour | 141.0 |

## STANDARD OF PURIFICATION REQUIRED

The standard of purification of the effluent adopted by resolution of the Sewerage Commission is:

| | |
|---|---|
| Reduction of Bacteria | 90% |
| Reduction of Suspended Matter | 95% |
| Stability | 72 hrs. |

The long period of operation in the demonstration plant under varying conditions indicates that the average standard of purification will, at all times, surpass the above standard, provided the disposal plant is maintained at a high state of efficiency.

# BASIC DATA FOR DISPOSAL PLANT DESIGN

## General

| | |
|---|---|
| Capacity of Grit Chambers | 317 mil. gals. daily. |
| Capacity of Fine Screens | 317 mil. gals. daily. |
| Capacity of Aeration and Sedimentation Tanks | 85 mil. gals. daily average. |
| | 128 mil. gals. daily maximum. |

## Aeration Tanks

| | |
|---|---|
| Rate of Treatment | 15 mil. gals. per acre per 24 hrs. |
| Capacity of each tank | 3,580,500 gals. per 24 hrs. |
| Time of Detention | Approximately 6 hrs. when carrying 20% by volume of activated sludge. |
| Ratio of Diffuser Area to liquid surface | 1 to 4. |
| Probable air requirements | 1.5 cu. ft. of air per gal. of sewage treated. |
| Surface area of one tank | Approximately 10,058 sq. ft. |
| Depth of Tank (Effective) | 15 ft. |

## Sedimentation Tanks

| | |
|---|---|
| Rate of Sedimentation | 1600 gals. per sq. ft. of liquid surface per day. |
| Maximum velocity of flow through the tanks | 1.5 ft. per minute. |
| Capacity of each 98 ft. tank with 20% by volume of sludge in mixture | 13,680,000 gals. per day. |
| Surface area of a 98 ft. tank | 8550 sq. ft. |
| Depth of Tank at center | 15 ft. |

# DESCRIPTION OF DISPOSAL PLANT STRUCTURES and APPLIANCES

(See colored insert at the end of booklet.)

1 — Park Street Siphon

A double concrete sewer built in tunnel carrying all the sewage from the districts west and south.

The high level placed above is equivalent in size to 48" diameter.

The low level placed below is equivalent in size to 54" diameter.

2 — Erie Street Siphon

A double concrete sewer built in tunnel carrying all the sewage from the districts east and north.

The high level placed above is equivalent in size to 72" diameter.

The low level placed below is equivalent in size to 42" diameter.

Maximum capacity of the four siphons 317,000,000 gallons daily.

The high level sewage (about 80% of the total) will flow out by gravity, the low level must be pumped.

3 — Coarse Screen House

A brick building 52' x 53' x 25' high, housing the high level rack screens and the low level cage screens and the control valves over the riser shaft common to both siphons.

The exterior brick will be uniform in all the structures.

4 — High Level Risers

These two vertical sewers carry the high level sewage from both siphons by gravity and discharge it into the high level flume from which it passes through the plant entirely by gravity.

5 — Low Level Risers

These two vertical sewers carry the low level sewage from both syphons to the low level cage screen chambers.

6 — High Level Flume

Size, 10' wide x 6' deep. Across this flume is located the rack screen.

7 — Rack Screen-High Level

Consist of vertical bars 2" x ½" placed edgewise to the flow at 4-3/16" center to center. Cleaning is to be done by men with rakes.

8 — Cage Screens-Low Level

Made of ¾" dia. bars spaced 2¾" center to center in a frame 9' x 10'. There are two chambers with two cages in each. The cages are raised by hoisting engines and when one cage in a chamber is up the other must be down in place — which prevents the pumps from receiving any unscreened sewage.

9 — Conduit to Low Level Pump

A concrete tunnel 72" diameter which carries the sewage from the cage screens to the suction chamber in the pump well.

10—Low Level Pump Well

A circular well, 45' diameter by 35' deep, lined with white tile — sunk as an open caisson. The low level sewage will flow to the suction chamber in the well by gravity and will be lifted 25' to 30' into the high level flume.

11—Power House

A brick building 200' long, 93' wide, and 42' high. This building covers the low level pump well, the return sludge pump well and houses the turbo-generators for furnishing power and the turbo-blowers which supply the air to the aeration tanks and channels.

12—Return Conduit from Low Level Pumps

A 48" cast iron pipe connecting the discharge of the low level pumps to the high level flume. Included in this conduit is a venturi meter to measure the volume of sewage passing through the pumps.

13—Sewage Channel (Above): By-Pass (Below)

A double concrete flume, the upper section of which will convey the sewage from the riser shaft to the plant; the lower section is the plant by-pass. The upper channel is 10' wide by 6' deep; the by-pass is 10' wide by 5' deep.

14—Grit Chambers.

Consist of eight open concrete channels 8' wide, 8' deep and 95' long. The sewage passing through these channels is reduced to a velocity of 7.4 to 1.0 ft. per second which permits the mineral suspended matter to drop out. As this material accumulates in the bottom of a channel, it is to be removed by means of a clam shell bucket operated from a locomotive crane—the channel having been previously isolated and drained.

15—Overflow Chamber

Arranged with weirs which by-pass the sewage and prevent flooding of the fine screens in case of emergency.

16—Fine Screens

Built by the Link Belt Co., "Tark" type. Consist of eight revolving drums, 8' diameter by 8' long. Covered with manganese bronze plates 3/16" thick—having 27.5% of their surface slotted with openings 3/32" wide by 2" long.

Each screen is equipped with eight brushes for removing screenings.

Peripheral drum speed is 8 ft. to 12 ft. per minute.

Brush travel is 60 ft. per minute.

Capacity: 8" loss of head 149,760,000 gallons daily; 12" loss of head 317,000,000 gallons daily with all eight screens operating.

17—Fine Screen House and Administration Building

A brick building 100' long, 68' wide, 42' high. Two stories: lower for the screens; upper for the laboratory and administrative offices.

18—Overflow Chamber

Arranged with weirs which will ultimately by-pass a portion of the storm water flow.

The storm water flow referred to will pass through the grit chambers and fine screens but not through the aeration and sedimentation tanks.

19—Mixing Channel

A concrete conduit 14' wide by 11' deep in which the incoming raw screened sewage is mixed with returned activated sludge.

Maximum capacity 231,000,000 gallons daily.

20—Gate House

Part of west brick gallery, housing four 6' by 10' sluice gates which control the flow to the aeration tank feed channels.

21—Feed Channels

Four concrete channels 8' wide, 10' deep, 790' long which supply the mixture of raw sewage and activated sludge to the aeration tanks.

22—Sludge Conditioning Tanks

Four concrete tanks 45' 4" diameter by 15' deep, equipped with "Dorr Thickeners." Used for special conditioning of the sludge.

23—Aeration Tanks

Twenty-four rectangular concrete tanks, each having two parallel compartments 236' long, 22' wide with 15' effective depth. 2514 filtros plates, each 1 ft. square, will be placed in pre-cast concrete containers resting on the bottom of each tank. Air compressed from 8 lbs. to 10 lbs. per sq. inch will be supplied to each container and will be diffused through the filtros plates.

24—Mixed Liquor Channels

These are concrete conduits which receive the aerated liquor from the aeration tanks, and supply it to the sedimentation tanks.

25—Large Sedimentation Tanks

Eleven concrete tanks, each 98′ in diameter at the bottom with octagonal tops and with 15′ effective depth.

The sedimentation period is approximately thirty minutes.

Purified, clear effluent continuously overflows into the effluent troughs at the top of each tank and sludge is removed continuously from the bottom by means of hydrostatic head.

26—Effluent Troughs

Three steel troughs at the top of each sedimentation tank, 32″ wide, 18″ deep, 98′ long, which receive the clear effluent from the surface of the tanks.

27—Effluent Channels

Two concrete conduits 8′ wide, 16′ deep, 800′ long which convey the plant effluent from the effluent troughs to the lake outfall.

28—Return Sludge Channels

Two parallel concrete conduits 6′ wide by 11′ 6″ deep through the entire length of the center gallery which collect the activated sludge from the bottom of the sedimentation tanks. These channels are equipped with diffuser plates.

29—Outfall

Built of concrete at the end of the effluent channels. The effluent will be discharged into the lake at a depth of 14′ below the water level.

30—Return Sludge Channel To Pump Well

Of concrete construction, 54″ diameter. The sludge flows through this by gravity from the return sludge channels to the sludge well.

31—Sludge Suction Chamber

This is located at the north east corner of the power house. Here the sludge is pumped back into the mixing channels.

32—Return Sludge Pump Well

A rectangular structure lined with white tile housing the return sludge pumps.

33—Return Sludge Main to Mixing Channel

A 48′ cast iron pipe, equipped with a venturi meter, which carries the sludge back to the mixing channel.

34—Sludge Pipe to Filter House

An 18″ cast iron pipe carrying the excess sludge to the acidification tanks. This pipe connects with both the return sludge force main and the four small sedimentation tanks.

35—Acidification Tank

A 42,000 gallon submerged reservoir where acid is added to the excess sludge prior to filtering. This tank is to be equipped with diffuser plates to prevent sedimentation and to promote mixing of sludge and acid.

36—Machinery Bay

A brick structure 65′ wide, 175′ long, 45′ high to house the machinery for the operation of the filter plant.

37—Filter House

A brick structure 85′ wide, 175′ long, 45′ high to house the 24 vacuum filters.

38—Dryer House

A brick building 125′ wide, 150′ long, 45′ high—2 stories. The first floor houses six dryers; the second floor is for dry fertilizer storage.

Note: 36, 37, 38 and 73 are combined in a single structure.

39—Coal Storage Pocket

A concrete pit 50′ wide, 180′ long, 12′ deep—capacity 2500 tons of coal.

40—Acid Storage Tank

Not yet designed.

41—Boiler House

Built of brick—165′ long, 68′ wide, 55′ high inside. This building houses four high pressure boilers, and the other steam making appliances. On the tower roof at the southeast corner is placed the storm signal tower of the federal weather bureau.

42—Stack

Built of the same exterior brick as the other structures. Total height is 211′ with an inside diameter of 12′.

43—Turbo-Generators

Three Allis-Chalmers Co. horizontal high pressure condensing turbo-generators. Capacity of each 625 k. w. at 80% power factor. Speed 3600 r. p. m. Current, 3 phase, 60 cycle, 480 volts.

44—Turbo-Blowers

Four Ingersoll Rand Co. blowers—turbo type—each directly connected to an Allis-Chalmers Co. horizontal high pressure multi-stage steam turbine, operating at 3600 r. p. m. Each turbo-blower will compress 35000 cu. ft. of free air per minute to 10 lbs. pressure. The air required for 85,000,000 gallons sewage is approximately 127,500,000 cu. ft.

45—Air Washers

Four Spray Engineering Co. air washers located in the inlet pipes to the blowers will deliver air without free moisture or dirt. Not more than ten gallons of water are required to wash 1000 cu. ft of air.

Clean air is necessary to prevent the filtros plates from clogging. About 90% of the air supplied will be used for mechanical agitation.

46—Air Main

A 72" cast iron pipe supplying air to approximately 75,000 filtros plates.

47—Dock

A concrete dock wall on wooden piling.

48—Present River Line to be Renewed

Reserved for future harbor development.

49—Testing Station to be removed

50—Government Pier

On the south side of the harbor entrance.

51—Bulkhead

Built of stone and wooden piling. It surrounds the aeration and sedimentation tanks. The shore line formerly came within twenty feet of the east wall of the power house.

52—Property Limit

53—Railroad Tracks

54—Low Level Pumps

Three Allis-Chalmers Co. automatically controlled single stage, vertical shaft, centrifugal pumps. Each unit is driven by a 250 h. p. variable speed wound rotor motor capable of operating at one-half, three-quarters and full speeds.

Capacity of each pump at full speed is 30,000,000 gallons per day, lifted thirty-five feet.

55—Return Sludge Pumps

Three Allis-Chalmers Co. automatically controlled, single stage, double suction, vertical shaft pumps. Each unit is driven by a 50 h. p. variable speed, three phase alternating current, induction motor.

Capacity of each pump at full speed, 12,000,000 gallons daily.

Capacity of each pump at ¾ speed, 9,000,000 gallons daily.

Capacity of each pump at ½ speed, 6,000,000,000 gallons daily.

56—Economizers

Two B. F. Sturtevant Co. economizers—each serving two boilers. Each unit has 528 tubes 12' long with an effective heating surface of 8500 sq. ft. The stack temperature will be approximately 287° F., based on 218,000 pounds of gas per hour entering the economizer at approximately 575° F. when the boilers are operating at 200% rating.

57—Boilers

Four Heine 784 h. p. boilers—each having 418 3½" tubes 18' long with a total heating surface of 7840 sq. ft., and designed for a working pressure of 225 pounds per sq. inch at a temperature of 518° F. The overload rating is 200% continuously.

To remove soot the boilers are equipped with Diamond soot blowers.

Each boiler is provided with a seven retort Westinghouse underfeed stoker having an effective coal burning area of 114.8 sq. ft.; a turbine driven forced draft fan of the Sturtevant type operating at 1190 r. p. m. having a capacity of 21,700 cu. ft. of air per minute; and an engine driven induced draft fan of the Sturtevant type having a capacity of 53,330 cu. ft. of air per minute.

A Foster superheater is furnished for each boiler.

Ash hoppers are furnished by Baker-Dunbar-Allen Co.

Ashes from the ash pits and soot from the boiler soot chamber and the stack will be removed by means of a Conveyors Corporation of America steam jet ash and soot conveyor.

58—Track Hopper

Coal handling equipment, furnished by the Chain Belt Co., consists of a track hopper; coal crusher—35 tons per hour capacity; positive discharge bucket elevator; belt conveyor with automatic tripper; and a coal bunker of 650 tons capacity.

59—Water Softener

This is furnished by the Wayne Tank and Pump Co. and consists of two vertical circular pressure filters 96" diameter and two vertical circular water softeners 96" diameter using the cold zeolite process.

60—Feed Water Heater and Pumps

Two Cochrane multi-feed water heaters each having a capacity of 150,000 pounds of water per hour; two Allis-Chalmers Co. single stage low lift motor-driven centrifugal pumps; two five stage motor-driven centrifugal pumps; and one five stage steam turbine-driven centrifugal boiler feed pump.

61—By-Pass

A concrete channel through which the sewage can pass if the grit chambers, sewage flume, fine screen plant, or aeration and sedimentation tanks are shut off.

62—Condensers - Pre-Heaters

Two in number—one to be used as a spare.

The condenser is used in connection with the heat exchangers when it is found advantageous to heat the sludge for efficient filtration. It is also arranged to function as a condenser only when the heat exchangers are by-passed.

63—Turbo-Generator

One Allis-Chalmers Co. 1250 k. w. turbo-generator, arranged to operate condensing or non-condensing, functioning as a heat balancing unit. When the sludge needs to be heated to any predetermined temperature exhaust steam from the turbo-generator will be automatically utilized. The power generated by this unit will float on the line connecting its switchboard with the main switchboard in the power house.

64—Vacuum Pumps and Air Compressors

Three Worthington, Laidlaw type, duplex two-stage reciprocating vacuum pumps operated by unaflow prime movers and having a piston displacement of 10,400 cu. ft. per minute each. These pumps will provide the high and the low vacuums for the vacuum filters.

Two Worthington, Laidlaw type, synchronous motor driven air compressors having a piston displacement of 625 cu. ft. per minute at 100 pounds pressure.

65—Condenser and Sludge Pumps

Three Allis-Chalmers Co. motor-driven centrifugal pumps which pump the sludge from the acidification tanks through the heat exchangers and preheaters to the filters. When sludge is not to be heated these pumps will supply the water for the condensers for the turbo-generator.

66—Heat Exchanger

Ten Griscom-Russell Co. heat exchangers having a total of about 19,500 sq. ft. of heating surface. In these the temperature of the cold sludge is raised from 50° F. to 140° F. by means of the heat in the hot filter effluent which enters the exchangers at 160° F. and discharges therefrom at 62.5° F.

67—Condensers

Three specially designed spray condensers manufactured by the Oliver Continuous Filter Co. These condition the air before it is drawn into the vacuum pumps.

68—Receivers

Four Oliver Continuous Filter Co. receivers to separate the air from the hot filtrate after it leaves the filters.

69—Coal Hopper and Stokers

Each dryer is equipped with a Coxe forced draft traveling grate stoker which receives its supply of coal from an individual coal hopper above.

70—Dryers

Six Atlas Dryer Co. direct-indirect-heat continuous rotary dryers 7′ diameter by 60′ long enclosed in brick settings. As the drum revolves the hot gases from the furnace mixed with large volumes of outside air circulate around and into the drum through numerous air valves attached to the drum shell.

From the filters these dryers receive the cake at a moisture of about 80% and deliver the finished material at a moisture of 5% to 10%.

71—Gate House

Two brick buildings 38′ long, 26′ wide, 18′ high on each end of the grit chambers, enclosing the sluice gates which control the flow through the chambers.

72—Service Pipe Tunnel

This carries the steam mains and conduits from the boiler house to the filter house.

73—Repair Shop

A brick structure 65′ wide, 175′ long, 45′ high to be used for repair work, fertilizer storage, etc.

74—Vacuum Filters

Twenty-four Oliver Continuous Filter Co. vacuum drum filters each 11′6″ diameter and 14′0″ long with 495 sq. ft. effective filtering surface.

These filters will dewater the 98% to 99% sludge from the sedimentation tanks to a ribbon-like cake containing from 75 to 80% moisture.

75—Dried Sludge Storage Building

Plans not yet completed.

76—Dorr Thickener Trusses.

Structural steel trusses spanning the sedimentation tanks to support the Dorr Thickener driving mechanism in each tank. This mechanism is driven by independent variable speed motors. The four arms with their "plows" are attached to a vertical revolving shaft hung from the driving mechanism.

The arms sweep the entire bottom of the tank and rotate slowly making one complete revolution in approximately 22 minutes which speed, however, can be varied according to the condition of the sludge. The function of the thickeners will be to scrape the sludge settling on the bottom of the tanks towards the center where it will be drawn off.

77—Filtrate Outlet

Yet to be designed.