CASE HISTORIES:

IMPROVED ACTIVATED SLUDGE PLANT PERFORMANCE BY OPERATIONS CONTROL

A. W. West - P.E.
Sanitary Engineer

Field Investigations Branch
Division of Technical Support

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
U. S. DEPARTMENT OF THE INTERIOR
CINCINNATI, OHIO

APRIL 1969

ENVIRONMENTAL PROTECTION AGENCY

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INTRODUCTION

Firsthand operation experiences during Federal Water Pollution Control Administration Technical Assistance Projects at the Sioux Falls, South Dakota, and the St. Louis, Missouri, activated sludge treatment plants document once again the excellent final effluent quality that can be produced by presently available secondary treatment processes. In these two cases, final effluent quality was greatly improved by modifying process control procedures, and at practically no extra cost. In one case, 99 percent BOD and suspended solids removals were obtained with readily available present day treatment processes and equipment.

Activated sludge plants can produce final effluents containing considerably less than 10 mg/l suspended solids and 5-day biochemical oxygen demand (BOD). Overall reductions of 95 to 99 percent are possible. Some of these past experiences, especially those at Sioux Falls confirm that there is no need to approve, or accept, secondary treatment systems capable of producing only 85 percent reductions.

Certain essential requirements must be met, however, if consistent effluent excellence is to be expected. The treatment plant must be properly designed with adequate built-in capacity and flexibility; plant characteristics must be appropriate to the incoming load; and the process must be skillfully controlled by conscientious qualified operators.

Performance of the Sioux Falls and St. Louis plants was measured by the routine BOD and suspended solids reductions determined by the plant chemists. Though a detailed study of nutrient removals was not included, a few scattered tests indicated only low level phosphorus removals ranging from about 0 to 35 percent. No appreciable nitrification or denitrification was observed.

Operational control adjustments were predicated upon the results of the following tests:

1. Mixed liquor and return sludge specimens were centrifuged to determine sludge concentration and distribution.
2. Mixed liquor sludge settling and compaction rates, observed in a laboratory cylinder, revealed sludge condition.
3. The measured sludge blanket depth in the final clarifier revealed process balance.
4. Air discharges were regulated according to measured dissolved oxygen concentrations in the aeration tanks.

METROPOLITAN ST. LOUIS SEWER DISTRICT - MSD

Coldwater Creek (Activated Sludge Type)
Wastewater Treatment Plant

A. PLANT DESCRIPTION

The conventional standard rate activated sludge plant had a rated capacity of 21.0 MGD with 6 aerators, each of which is equipped with spiral flow pattern air diffusers and 4 final clarifiers, each equipped with plow-type sludge scrapers.

B. PLANT PERFORMANCE

The pollutional strength of the final effluent from this plant was reduced to one-fourth of its former strength by modified operational control. The wholehearted support and cooperation provided by management, the recently appointed superintendent and the entire operating group contributed greatly to the success of this project.

Previously, the average final effluent contained 40 mg/l of BOD and 92 mg/l of suspended solids. The process responded favorably to modified control procedures, and during the last week of the project, the final effluent averaged 9 mg/l of BOD and 16 mg/l of suspended solids.

Other "before and after" characteristics are shown in the following Table 1:

TABLE NO. 1

SUSPENDED SOLIDS & BOD REMOVALS

at the

Coldwater Creek S.T.P.

		Before	After
Suspended Solids			
Raw	(mg/l)	173	198
Primary Effluent	(mg/l)	155	142
Final Effluent	(mg/l)	92	16
Activated Sludge Reduction		40%	89%
Total Plant Reduction		46%	92%
5-Day BOD			
Raw	(mg/l)	150	162
Primary Effluent	(mg/l)	152	130
Final Effluent	(mg/l)	40	9
Activated Sludge Reduction		74%	93%
Total Plant Reduction		73%	94%

C. IMPROVED OPERATIONAL CONTROL

1. Number of Aerators and Clarifiers in Service

Before changes were made, the activated sludge looked old and septic, smelled bad, and was settling too rapidly. Too many clarifiers, and too few aerators were in service. One of the four clarifiers was taken out of service and one additional aerator was placed in service to augment the three operating units. The computed characteristics of the 3 aerator - 4 clarifier vs. the 4 aerator - 3 clarifier activated sludge systems were changed as shown in the following Table 2:

TABLE NO. 2

COMPUTED PLANT CHARACTERISTICS

Coldwater Creek S.T.P.

	Former	Changed To
Aerator-Clarifier Combination	3A/4C	4A/3C
Mixed Liquor Suspended Solids	7,200	3,400
Return Sludge Flow (% of Sewage Flow)	93	30
Flow Capacity (MGD)	13.2	14.5
Aerator Detention (HRS)	3.0	5.4
Clarifier Detention (HRS)	2.0	2.0

The 4 aerator - 3 clarifier combination provided a more practical theoretical mixed liquor suspended solids concentration demand of approximately 3,400 mg/1 as opposed to the impractical 7,200 mg/1 demand of the former 3 aerator - 4 clarifier combination. Similarly, calculations indicated that the revised plant combination could be operated at 30 percent return sludge, whereas the old combination required in excess of 90 percent return sludge.

2. Control Tests

The standard 1-liter graduated cylinders were replaced by the larger diameter (5" dia. x 6" deep) 2-liter Mallory Direct-reading Settleometers for mixed liquor sludge settling rate determinations. Each mixed liquor specimen was settled for one hour, and the volume of the cylinder occupied by the settled sludge was recorded at every 5-minute interval during the first half-hour and at every 10-minute interval during the second half-hour. Mixed liquor and return sludge specimens were centrifuged for 15-minute periods to determine their relative densities and the solids distribution ratios. Sludge concentration characteristics were computed from the settling and centrifuged tests.

The thickness of the settled sludge blanket in the final clarifiers was measured periodically with a sludge blanket finder.

The dissolved oxygen concentration in the aeration tanks was measured to indicate air discharge requirements.

Relative final effluent quality trends were determined rapidly with a turbidimeter.

3. Control Adjustments

In this case operations and effluent quality were improved by:

Increasing the excess sludge wasting rate to reduce sludge age.

Reducing the return sludge pumping rate to conform to the requirements of lowered mixed liquor sludge concentrations.

Increasing the air supply and then adjusting it to try to maintain between 1.0 and 3.0 mg/l of dissolved oxygen in the aeration tanks.

D. FAVORABLE FEATURES AT EXISTING PLANT

The extensive improvements would not have been possible without the dedicated and effective cooperation provided by the Superintendent and operators.

Adequate tank capacity in multiple aerator and clarifier units were available to permit changing the process characteristics and to accommodate present dry-weather flows.

E. PLANT DEFICIENCIES

1. Plow-type sludge scrapers increased the settled sludge detention time in the anaerobic environment of the final clarifiers.
2. "Spiral flow" air diffuser placement limited mixing and oxygen transfer rates in the aerators.
3. Hydraulic short circuiting plus strong velocity currents in final clarifiers were at times directly responsible for carrying increased amounts of suspended solids to the final effluent.
4. No scum removal devices were provided for the final clarifiers.
5. Return sludge capacity was limited.
6. Meter problems, and lack of remotely controlled mechanical valve actuators or automatic sensor-controllers limited process controllability.

F. FUTURE POTENTIAL

The problems encountered at this plant indicate that the pollutional load in the effluent can be cut in half once again when the more significant constricting plant deficiencies are corrected.

SIOUX FALLS, SOUTH DAKOTA

A. PLANT DESCRIPTION

Approximately 3.5 mgd of strong 2,500 mg/l BOD meat-packing waste plus 6.0 mgd of normal domestic sewage were treated at Sioux Falls. The packing plant waste was settled, pretreated in high-rate trickling filters, and then combined with raw domestic sewage for discharge to primary clarifiers. The activated sludge system treated the settled domestic sewage and polished the pretreated industrial wastes.

The aeration tanks, which operate as "complete-mix" units, are provided with effective "turbine" type aerators. The "rim-flow" final clarifiers are equipped with appropriate suction type sludge removal mechanisms.

B. PLANT PERFORMANCE (Fall of 1968)

During the October and November 1968 technical assistance project, when the plant is severely overloaded, the pollutional strength of the final effluent was reduced to about one-half of its former strength by modified operational control.

During the summer months, when plant loadings are within design capacity, the superintendent achieves remarkable reductions through the plant.

During late fall and early winter, however, industrial waste loads increase with the increased kill at the meat-packing plant, trickling filters freeze, the activated sludge unit is greatly overloaded, and effluent quality suffers.

1. Significant Loading Characteristics

The more significant October-November 1968 loading characteristics that influence performance of this plant were shown on Table 3. Aerator loadings, which were high at all times, averaged 117 pounds of BOD per 1,000 cubic foot of aerator. The waste load to activated sludge solids ratio usually exceeded 1.0 pound of BOD per pound of mixed liquor solids. (Normal design loadings for conventional activated sludge plants are usually less than 50 pounds of BOD per 1,000 cu. ft. of aerator and less than 0.5 pounds of BOD per pound of mixed liquor solids.)

Clarifier surface loading rates were more normal and averaged 650 gallons per square foot per day. Aeration detention times ranged from about 1.5 to 3.0 hours.

TABLE NO. 3

ACTIVATED SLUDGE PLANT LOADINGS
Sioux Falls, South Dakota

ACTIVATED SLUDGE PLANT LOADINGS	Oct. & Nov. 1967	Oct. & Nov. 1968
BOD to Aerators		
Pounds per day	26,700	27,300
Pounds per 1,000 cu.ft. aer.	115	117
Clarifier Loadings		
MGD Final Effluent	10.0	9.8
Gals./Day/Sq.Ft.	660	650

2. Control Tests

Here again settlometers, centrifuges, sludge blanket finders and turbidimeters were introduced to detect sludge conditions, process balance and operational control demands.

3. Control Adjustments

The effluent quality was improved by increasing the return sludge percentages from about 30 percent to as high as 200 per cent and by "tight-rope" sludge wasting control to increase mixed liquor sludge concentrations from about 1,000 to 3,000 mg/l without upsetting the aerators and clarifiers. The plant was greatly overloaded and more aerators and clarifiers, especially aerators, are needed to handle the organic overload to the activated sludge system.

4. Results

Final effluent quality produced in 1968 is compared with that obtained during the fall of 1967 when influent loadings were similar (Figures 1 and 2). The average BOD had been reduced from 30 to 20 mg/l and the average suspended solids concentration from 35 to 14 mg/l. The pollutional loading to the Big Sioux River had been reduced almost one-half by the modified control procedures.

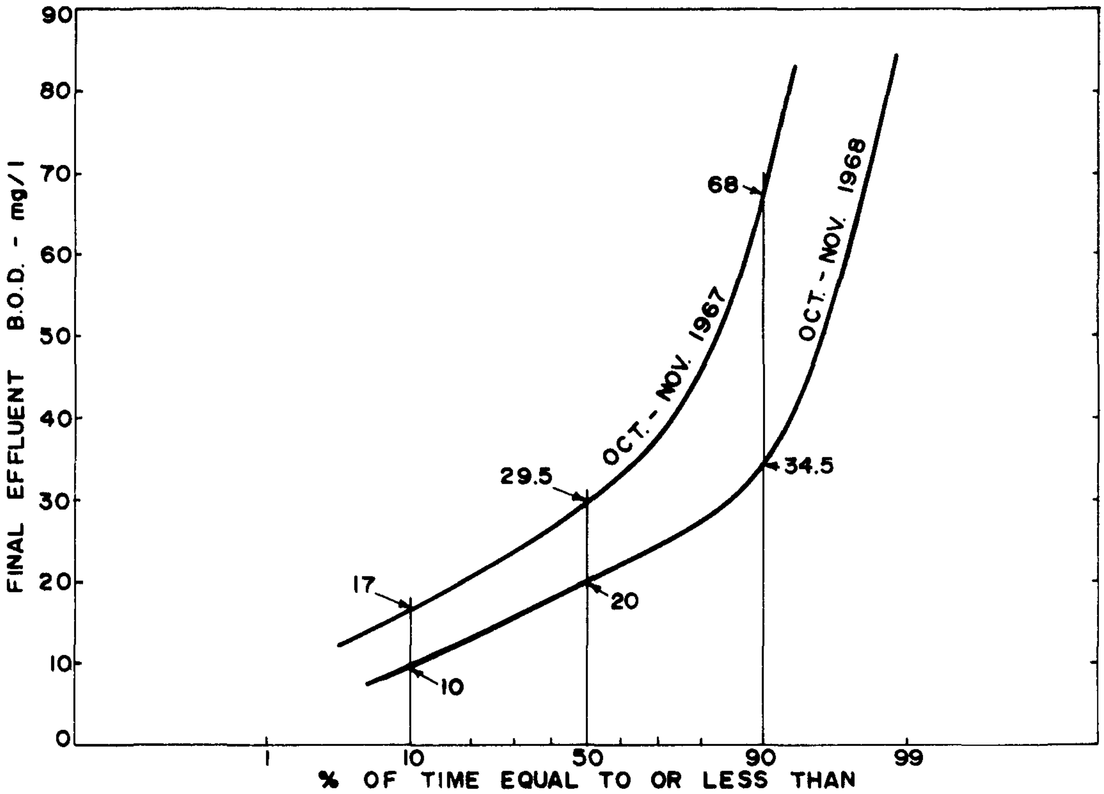

FIGURE 1 — SIOUX FALLS, S.D. FINAL EFFLUENT 5 DAY B.O.D. MONTHS OF OCT. & NOV. 1967 VS. 1968.

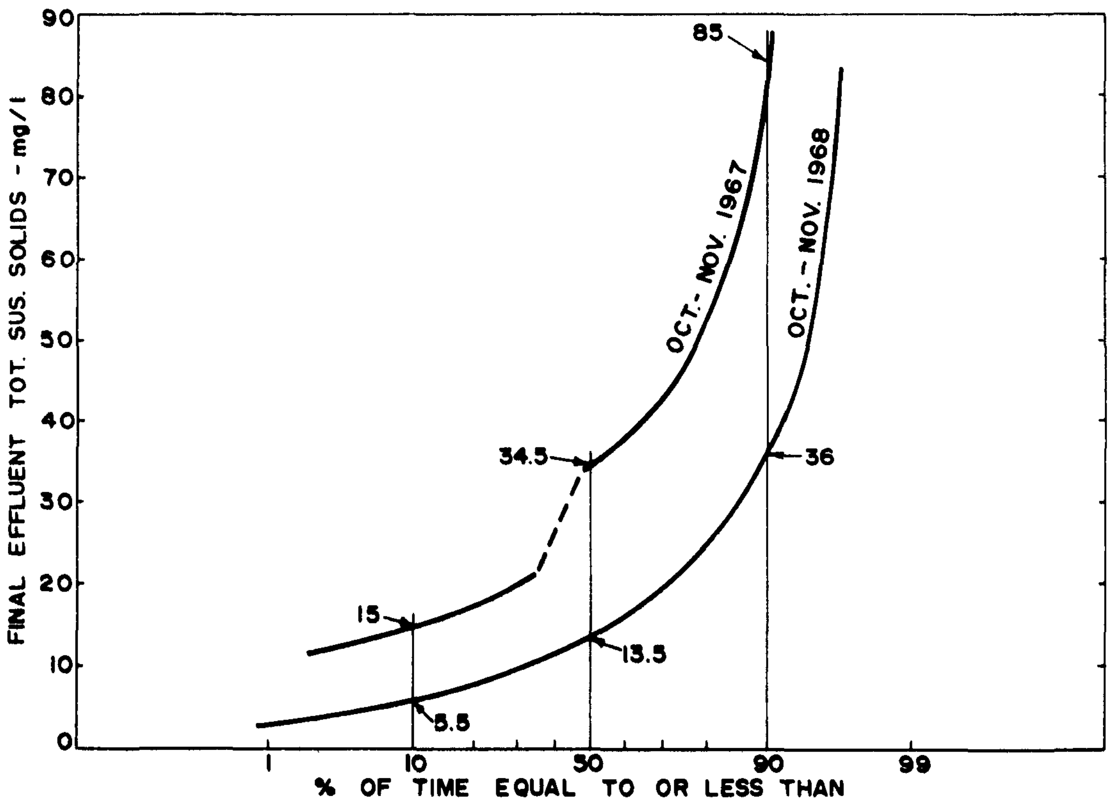

FIGURE 2 — SIOUX FALLS, S.D. FINAL EFFLUENT TOTAL SUSPENDED SOLIDS MONTHS OF OCT. & NOV. 1967 VS. 1968.

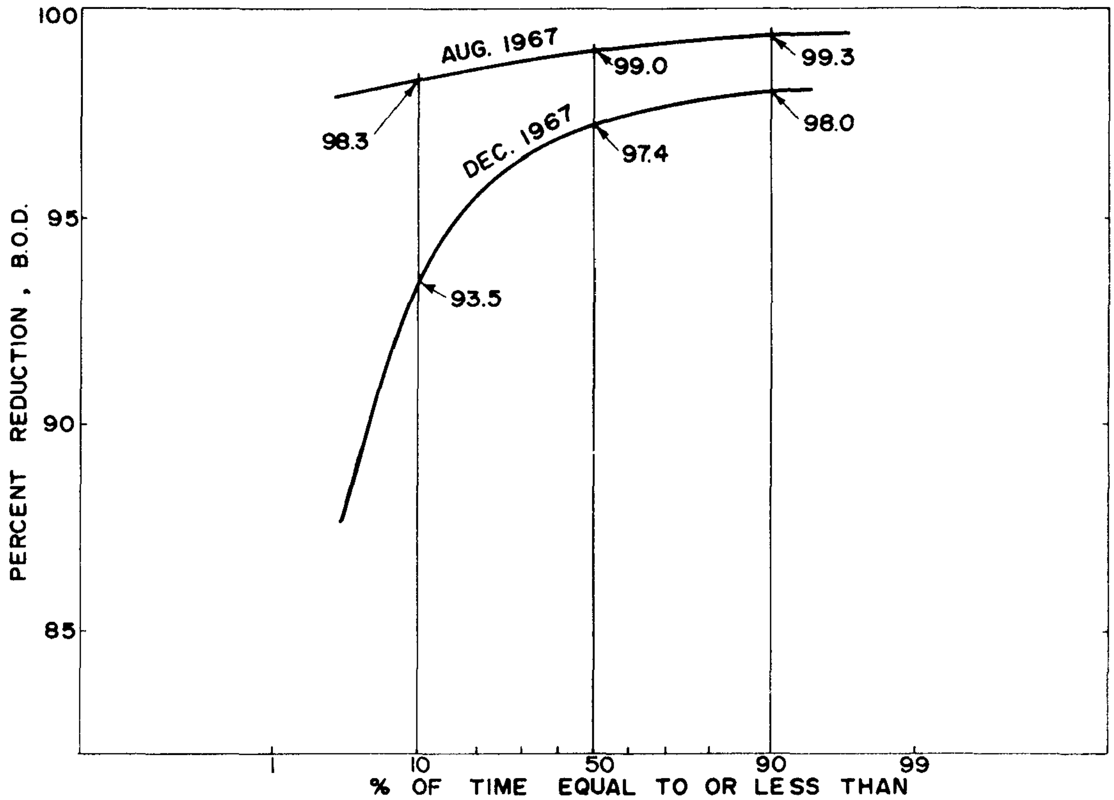

FIGURE 3 — SIOUX FALLS, S D 5 DAY BOD REDUCTIONS THROUGH ENTIRE PLANT (AUG. & DEC., 1967).

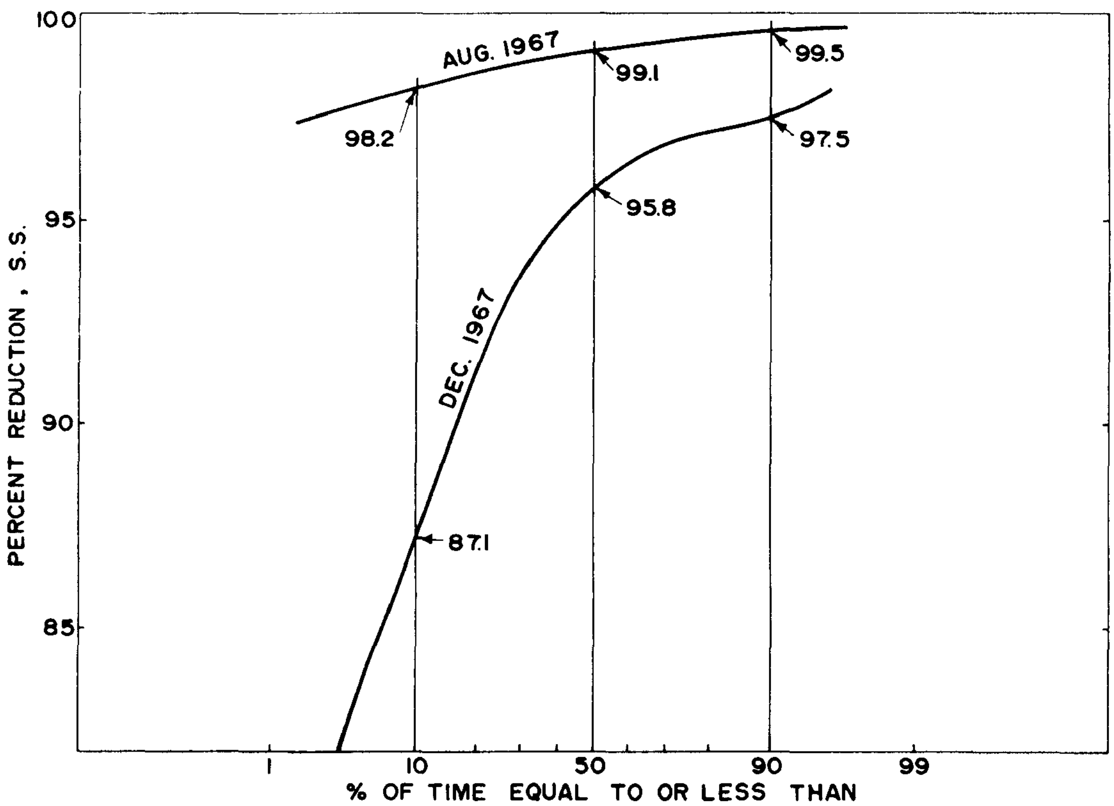

FIGURE 4 — SIOUX FALLS, S.D. SUSPENDED SOLIDS REDUCTIONS THROUGH ENTIRE PLANT (AUG. & DEC., 1967).

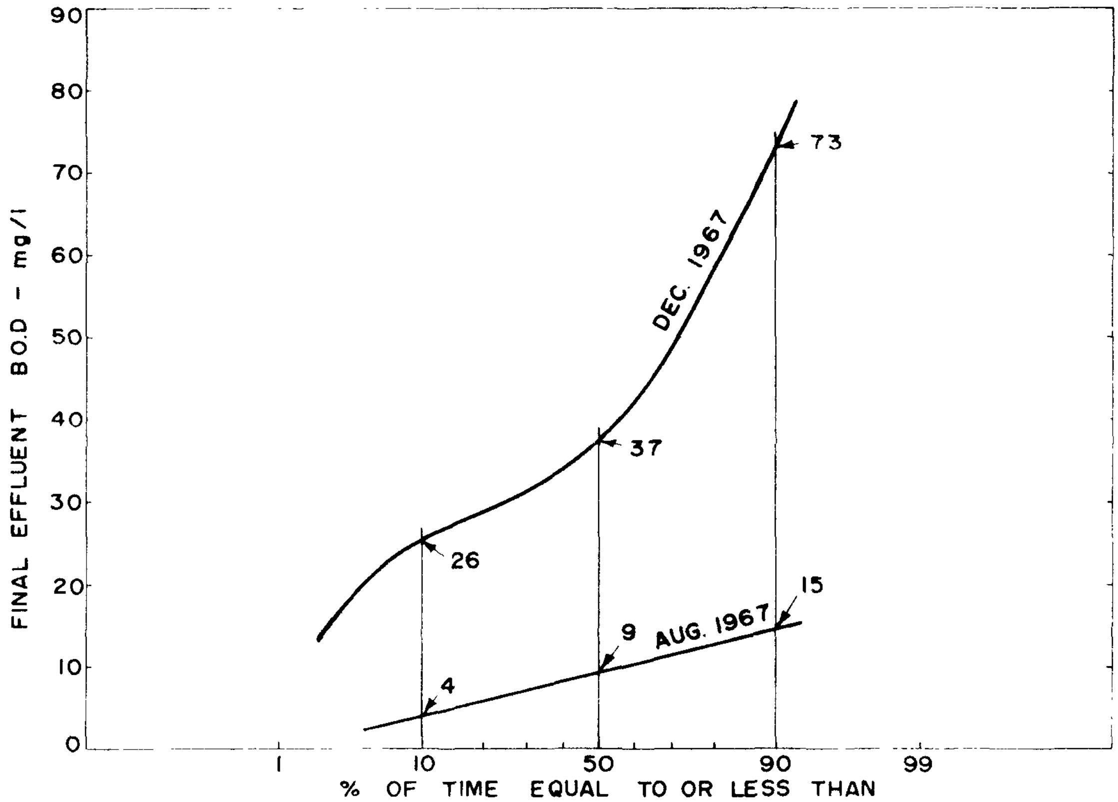

FIGURE 5 — SIOUX FALLS, S.D. FINAL EFFLUENT 5 DAY BOD MONTHS OF AUG. & DEC., 1967.

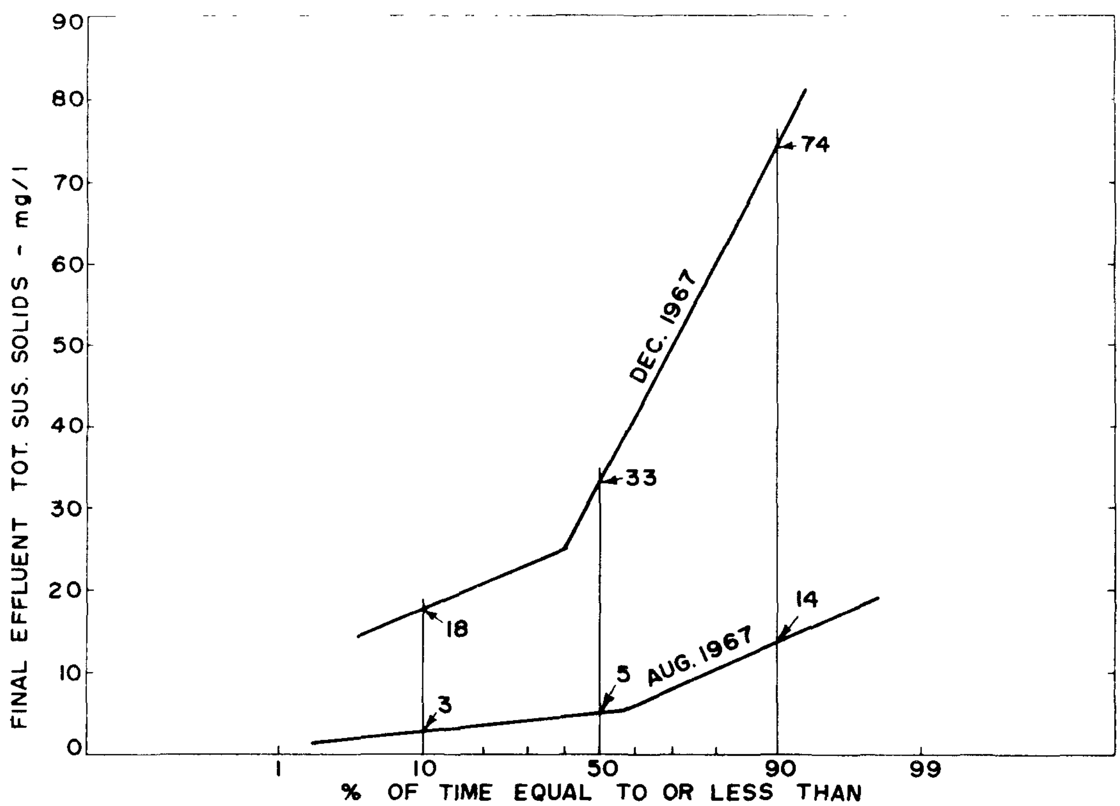

FIGURE 6 — SIOUX FALLS, S.D. FINAL EFFLUENT TOTAL SUSPENDED SOLIDS MONTHS OF AUG. & DEC., 1967.

C. PLANT PERFORMANCE (Summer 1967)

The feature story at this plant relates to the Superintendent's ability to obtain 99 percent BOD and suspended solids reductions during summertime when the plant loadings remain within designed capacity.

Percent reductions during the summer (August) and the winter (December) are illustrated on Figures 3 and 4, and the effluent quality (in terms of BOD and suspended solids concentrations) is shown on Figures 5 and 6.

During August 1967 the combined BOD of the combined industrial and domestic wastes averaged 900 mg/l and was reduced to an average of 9 mg/l in the final effluent. Similarly, total suspended solids were reduced from 650 to 5 mg/l. These are remarkable reductions; especially in view of the high BOD loadings shown in Table 4.

TABLE NO. 4

SIGNIFICANT LOADING CHARACTERISTICS
(Sioux Falls, South Dakota, Activated Sludge Plant)
Summer vs. Fall 1967

	SUMMER (Aug. 1967)	FALL (Dec. 1967)
BOD Load to Aerators		
Pounds per day	18,000	37,400
Pounds per 1,000 cu.ft. Aerator	103	160
Pounds per pound mixed liquor solids	1.3	1.2
Clarifier Surface Loading Rate		
Gals./sq.ft./day	720	640
BOD Reductions		
Total - Raw to Final	99	97
Activated Sludge Alone	95	90
TSS Reductions		
Total - Raw to Final	99	96
Activated Sludge Alone	96	83

D. FAVORABLE FEATURES AT THE EXISTING PLANT

1. Dedicated, skilled supervision and operation are primarily responsible for the unusually high purification efficiencies developed at this plant.
2. The aeration tanks were equipped with effective turbine-type aerators, rather than the less efficient conventional spiral flow types. (Compressed air was discharged through sparger rings located at the bottom of the aerators below mixing paddles.)
3. The aerators operated as "complete mix" (rather than "plug flow") systems.
4. The final clarifiers were equipped with suction-type (rather than scraper type) sludge removal mechanisms for rapid return of settled sludge to the aeration tanks.
5. Adequate return sludge pumping capacity, exceeding 150 percent of average raw waste flows, permitted over compensation when necessary.

E. PLANT DEFICIENCIES

1. Activated sludge plant was overloaded. It needed additional aerators.
2. Industrial waste trickling filters froze up in winter, and imposed greater loads upon the activated sludge system.
3. There was insufficient air to maintain 1.0 to 2.0 mg/l D.O. in aerators at all times.
4. Scum removers had not been provided for the final clarifiers.
5. Lack of sufficient meters, remotely controlled mechanical valve actuators, and automatic sensor-controllers limited process controllability.

CONCLUSIONS

Experiences at Sioux Falls and St. Louis provide confirmation that the activated sludge process can be operated at exceptionally high purification efficiencies to produce attractive clear final effluents.

They also highlighted the following design and operation requirements:

A. DESIGN

1. Provide adequate plant capacity for growth and for repairs during equipment outages.
2. Flexibility. (Give the operators a chance.) Provide ability to increase or decrease the number of aerators or clarifiers in service and to convert to modified activated sludge schemes such as "step aeration" if required.
3. Avoid "spiral flow" aeration.
4. Use suction devices in final clarifiers for rapid removal of fresh sludge. Also provide surface scum removers.
5. Make air supply, sludge return and sludge wasting equipment truly variable and conveniently controllable.
6. Provide essential meters and sensors, remote valve actuators and automatic ratio controllers where required.

B. OPERATION

1. Recruit and retain conscientious, intelligent, trained, and certified plant operators.
2. Provide practical "on-the-job" work experience type training.
3. Provide 24-hour operation. Test, evaluate and adjust process at least once every 8-hour shift.
4. Make best use of existing facilities and advise consulting engineers of operational requirements for plant additions and modifications.