UNOX DESIGN INFORMATION
FOR
CONTRACT DOCUMENTS

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By

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This presentation is designed to provide consulting engineers with design data, and municipal and regulatory agencies with information with which they can evaluate designs. This information was obtained from many sources, including research data from Middlesex County (New Jersey) Sewerage Authority; Washington, D.C.; and Batavia, New York, and design data from the Middlesex County Sewerage Authority and the New Rochelle (Westchester County) wastewater treatment plants which are completely or almost completely designed. The data presented are the best available but could be changed markedly when experience is gained in daily continuous operation.

A. The "Unox Activated Sludge Process" is a patented modification of the conventional activated sludge plug flow process which uses gaseous oxygen rather than air to maintain dissolved oxygen in the mixed liquor (See Figure 1 which is a schematic of the process). It can meet a much higher mixed liquor oxygen demand than any aerated modification. It can meet the oxygen demands of a more concentrated mixed liquor and of a higher volumetric BOD loading in the oxidation tanks. It may give the same BOD removals at higher F/M ratios. It effectively oxidizes dissolved BOD. It may have problems in removing suspended solids from mixed liquors in the final settling tank, especially in cold weather. It was

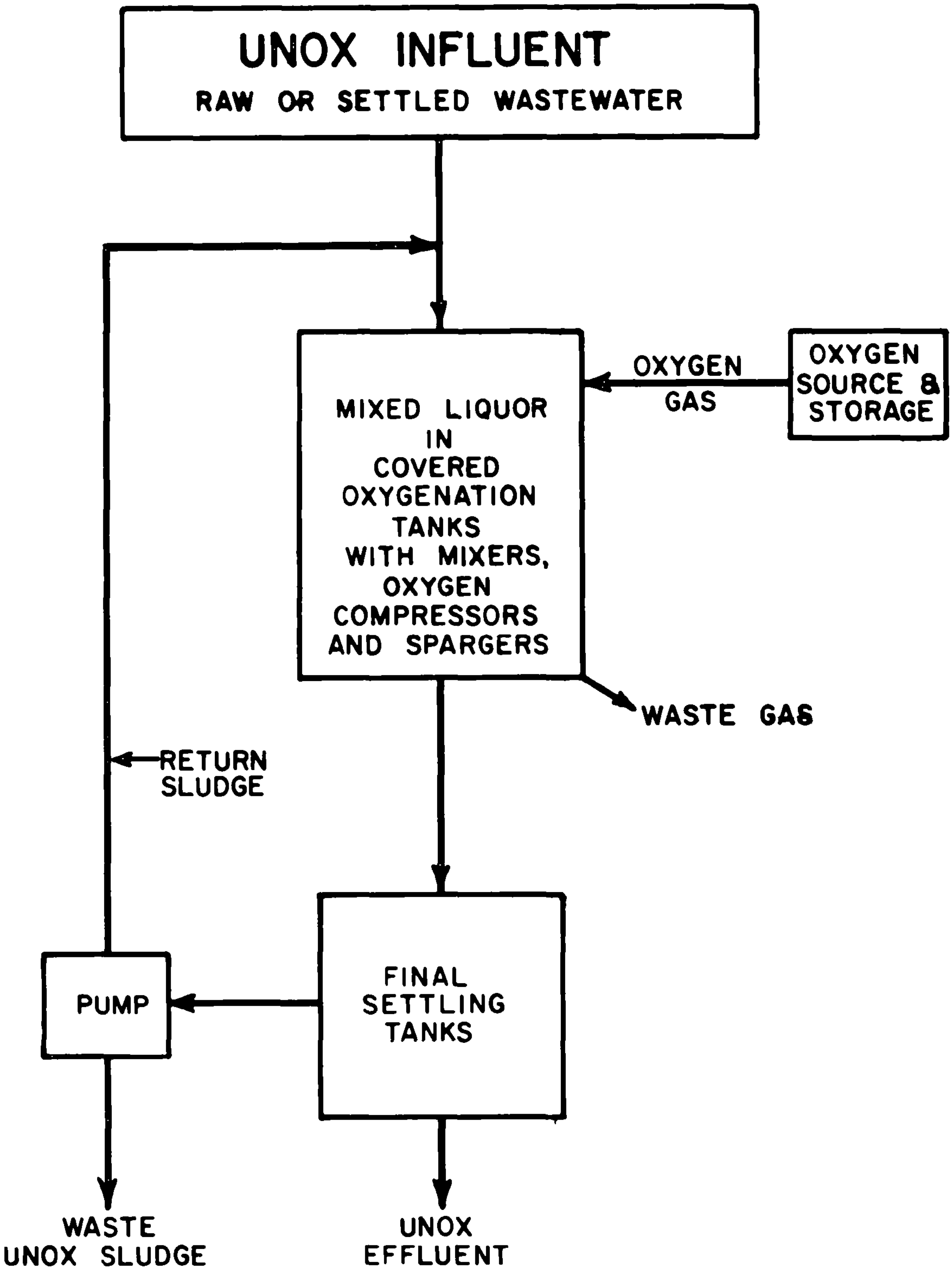

FIG. 1 UNOX PROCESS

more stable than the completely mixed and step-bio modifications of the activated sludge process in pilot plant operation with the MCSA wastewaters which are at least 50 percent industrial wastes.

Figure 2 is a schematic section of the pilot plant used at the Middlesex County Sewerage Authority. It is typical of a prototype four-stage oxygenation tank and final settling tank.

B. Design Data for the Oxygenation Tanks are presented below:

1. BOD removals, approximately 90%.
2. Tank volume based on 160 lbs of BOD_5/1000 cu ft. Unox believes that this can be increased to 215 lbs, or higher.
3. Mixed liquor suspended solids, 6500 mg/L.
4. Mixed liquor volatile suspended solids, 5500 mg/L.
5. F/MLVSS ratio, 0.465. Unox believes this can be much higher.
6. Mixed liquor dissolved oxygen is targeted at 3 to 9 mg/L.
7. Purity of applied gaseous oxygen.

Cryogenic	99.5%
P S A	90.0%

8. Oxygen in vest gas, 50%.
9. Applied oxygen utilized, 90%.

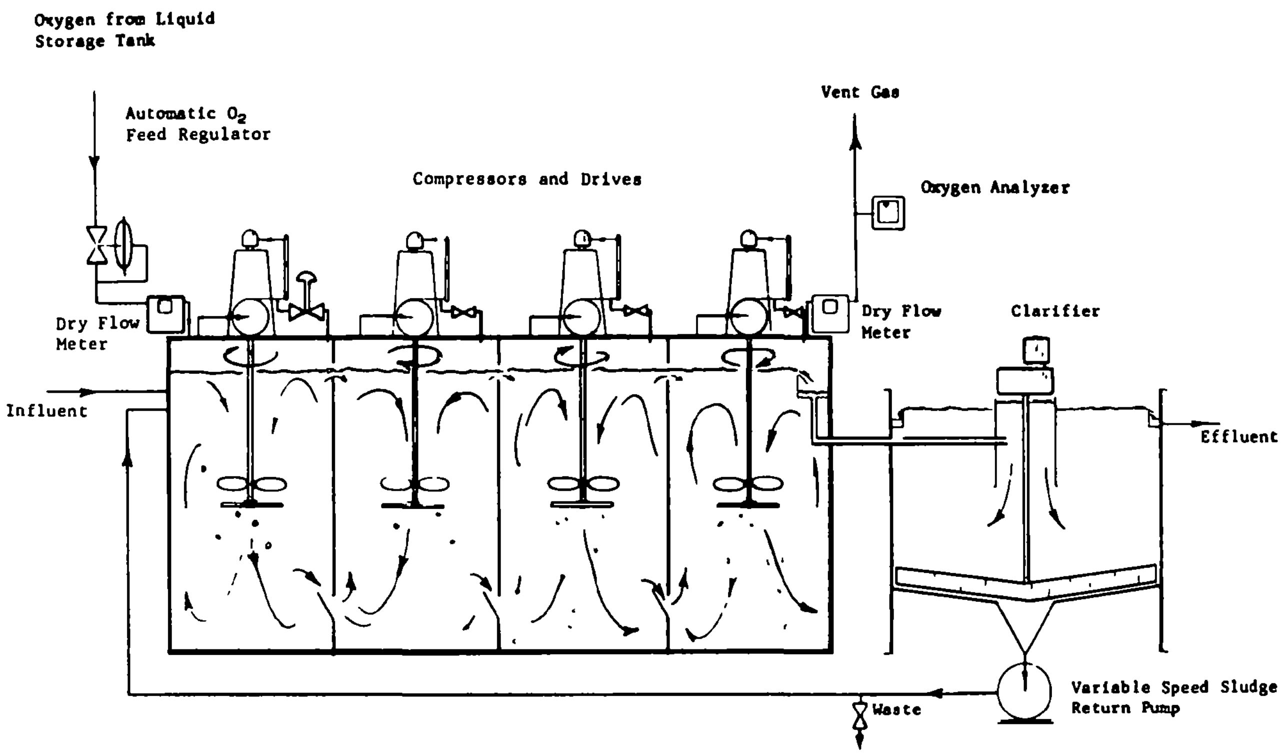

FIG. 2 MIDDLESEX COUNTY SEWAGE TREATMENT PLANT
"UNOX" PILOT FACILITY SCHEMATIC

10. Mixing Equipment and Sparger:

10.1 Sparger and mixer on same shaft.

10.2 Shaft is hollow and carries compressed oxygen to sparger.

10.3 Sparger and mixer turn at a constant speed which will keep contents of oxygenation tanks mixed.

10.4 Mixer is ship-type propeller.

10.5 Oxygen compressor for oxygenation tanks are centrifugal, with suction throttling.

10.6 For MCSA, mixer hp is 6000 and compressor hp is 5100, of which 1900 is standby. All of the mixer horsepower is connected and in operation at all times. MCSA expects that total power for mixing and dissolution will be less than 0.161 KWH per lb of oxygen dissolved.

10.7 Oxygen compressor suction pipes are subject to condensing and freezing of moisture in the oxygen gas stream in cold weather.

10.8 Special lubricants must be used if oxygen comes in contact with lubricant.

10.9 The mixer shaft rotates in a liquid seal which is cast into the top slab.

10.10 Spare mixer motor, speed reducer, shaft, propeller, and sparger must be stored on site.

10.11 Standby compressors must be installed for each oxygenation stage or, sometimes, one for two stages.

11. Normal oxygen pressure under covers of oxygenation tanks is 2 inches of water.

12. Tank covers designed for 100 lbs of live load and 4 inches of vacuum.

13. Oxygen feed into the first pass is controlled by pressure under the covers in the first pass. The approximate set point is 2 inches.

14. The pressure in the first pass is controlled by the rate of oxygen use and the purity of the gases vented to the atmosphere from the fourth pass. If the oxygen content is more or less than 50 percent, then the vent valve closes or opens, as necessary, to bring purity back to 50 percent.

15. Dissolved oxygen in each pass is controlled by the rate of discharge of compressed oxygen gas to that pass. The compressors can be controlled automatically or manually using DO meters.

16. Waste gas must be discharged into a stack approximately 15 feet high so that the waste oxygen will have a chance to mix before it reaches the ground.

17. BOD_5 applied to the oxygenation tanks varies during the day, daily, weekly, monthly, and with growth. The amount of oxygen required to meet the BOD_5 demand varies with the volumetric BOD_5 loading. As the loading increases the amount of oxygen required rises at a decreasing rate. See Figure 3, "Oxygen Demand Curve". You will note that, at the design loading of 160 lbs of BOD_5 per 1000 cu ft, 1.8 lbs of oxygen is required to remove 1 lb of BOD_5. As the loading increases to 255, the amount of oxygen required to remove 1 lb of BOD_5 drops to 1.1 lbs.

C. Design Data for Final Settling Tanks are presented below:

1. Overflow rate of maximum day is 1200 gal/sq ft/day.
2. Solids loading at MCSA will be 34 lbs/sq ft/day of tank area for design flow of 120 mgd with mixed liquor concentration at 5500 mg/L. This increases to 55 lbs/sq ft/day at maximum loading.
3. Sludge volume index must be looked at carefully. Sludge volume index is the volume in ml occupied by settled mixed liquor containing one gram of dry solid. The sludge volume index for a 2000 mg/L mixed liquor which settles to 25 percent in 30 minutes is 125. However, the sludge volume index of an 8000 mg/L mixed liquor which does not settle at all in 30 minutes is 125. Obviously, a good sludge volume index for conventional

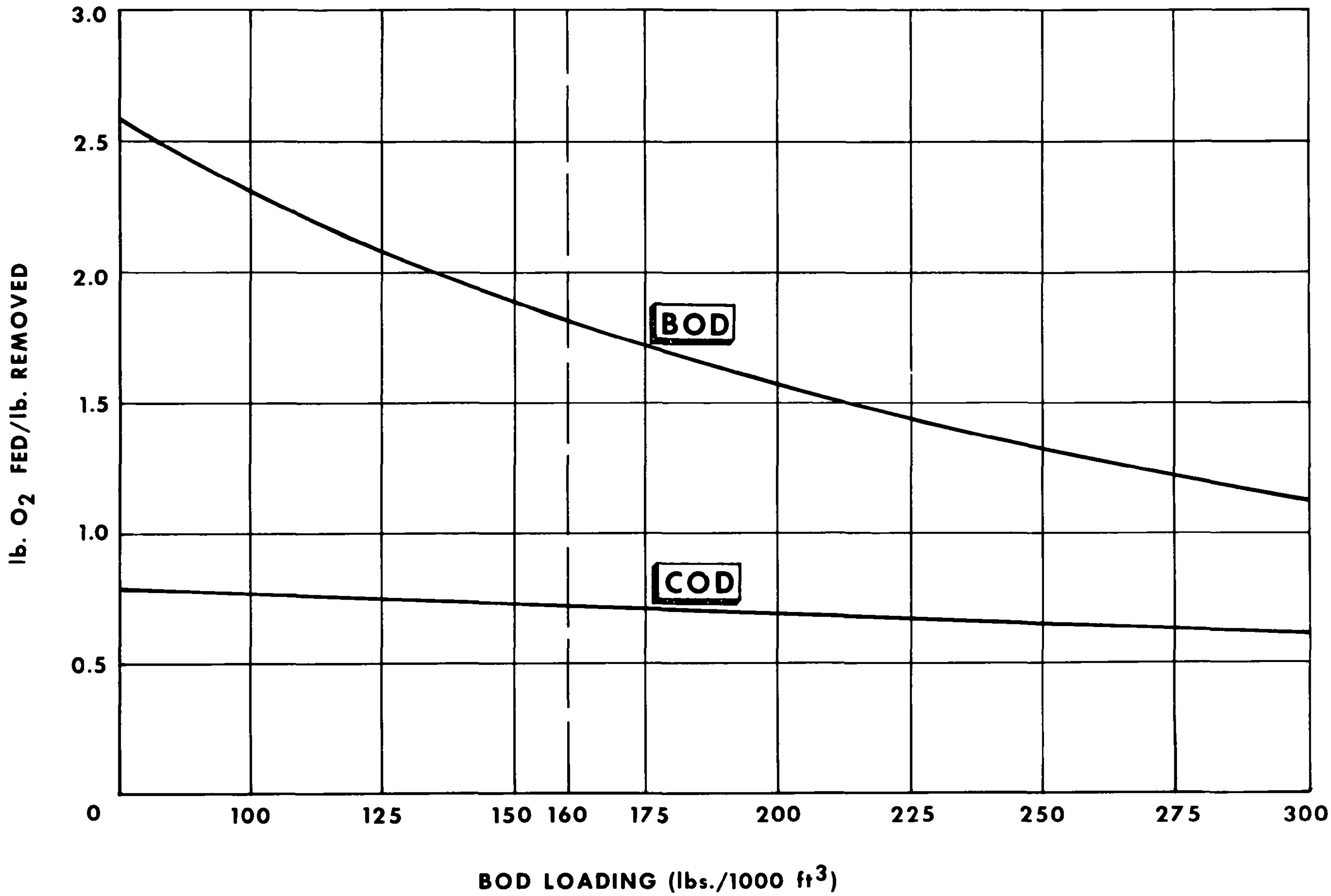

FIG. 3 OXYGEN DEMAND CURVE

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activated sludge may be very poor for Unox sludge which has a mixed liquor concentration in the final tank influent 2 to 6 times greater.

4. Settleability rates are a much better method for comparison. Figure 4 gives some indication of MCSA Unox sludge initial settling velocities.
5. Return sludge concentration varies from 1.5 to 3.0 percent. MCSA is designed for 2.2 percent.
6. Normal return sludge rate is 33 percent of influent wastewater flow. Maximum rate is 100 percent.
7. Union Carbide has preferred to have the rate of return sludge proportional to the Unox influent. This theoretically maintains the same mixed liquor concentrations in the oxygenation tanks. This is true at the moment the change is made because the return sludge concentration has not changed. However, an increase in mixed liquor flow of the same concentration reduced the period of retention of the liquid and the sludge and increases the overflow rate and solids loading rate with the possibility that solids separation will be reduced and the mixed liquor concentration will decrease. Union Carbide is having second thoughts on keeping the return sludge proportional to the Unox influent.

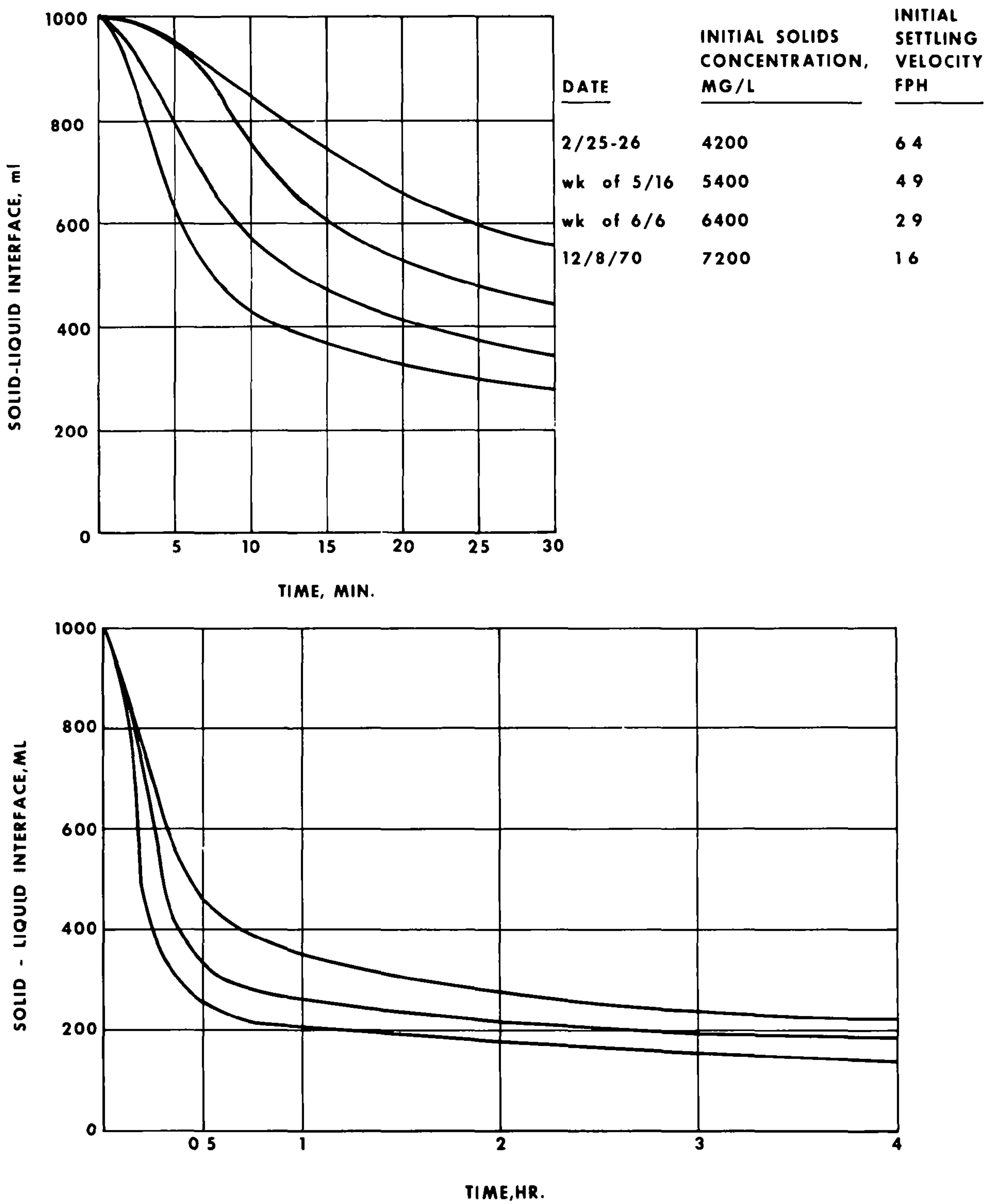

FIG. 4 TYPICAL SOLIDS SETTLEABILITY CURVES

D. Oxygen is produced by either the Cryogenic Process or the P.S.A. Process.

1. The Cryogenic Process is more economical for supplying more than 30 to 50 tons of oxygen per day.
2. The P.S.A. Process is more economical for less than 50 to 30 tons of oxygen per day.

E. The Cryogenic Oxygen Process has the following characteristics:

1. It can be supplied by at least 3 companies on a performance specification with quality requirements. It can best be considered as a "black box" piece of equipment except as its characteristics affect design of the wastewater treatment plant. This is similar to performance specifications for blowers, pumps, etc.
2. Cryogenic oxygen is produced by compressing and cooling air to a liquid and by separating oxygen and nitrogen by differential evaporation in the range of -300^{o}F. Oxygen boils at -297^{o}F.
3. Cryogenic oxygen plants can be turned down to approximately 2/3 of full capacity which, by coincidence, happens to be a normal turndown for large compressors. If all of the 2/3 plant capacity cannot be used, then the oxygen must be wasted to atmosphere through a stack.
4. A full standby for the primary compressor should be provided. At MCSA, for a 400-ton-per-day plant, the centrifugal compressor with adjustable inlet guide

vanes will be driven by an 8000 hp electric motor. The demand charges for running two compressors while changing from one to the other was so great that one compressor will be taken off line before the second one is started. This will result in up to two hours of lost oxygen production.

5. A full standby should also be provided for the turbine expander which is another large motor.
6. A cryogenic plant can produce liquid or gaseous oxygen (LOX or GOX) or various combinations of LOX and GOX, depending on how it is designed. The specifications for the MCSA plant will give the LOX and GOX capacities Shown on Figure 5. Each ton of LOX producted will reduce GOX by about four tons.
7. A cryogenic plant takes 1 to 3 days to start up, depending on whether liquid oxygen is available or not. It is not practical to meet variable demands by starting and stopping cryogenic units.
8. Dividing a cryogenic demand into two or more plants can help to economically meet the demands of a wastewater treatment plant at the beginning and end of the design period if it is serving a rapidly growing service area, but will not be useful for unpredictable variations.

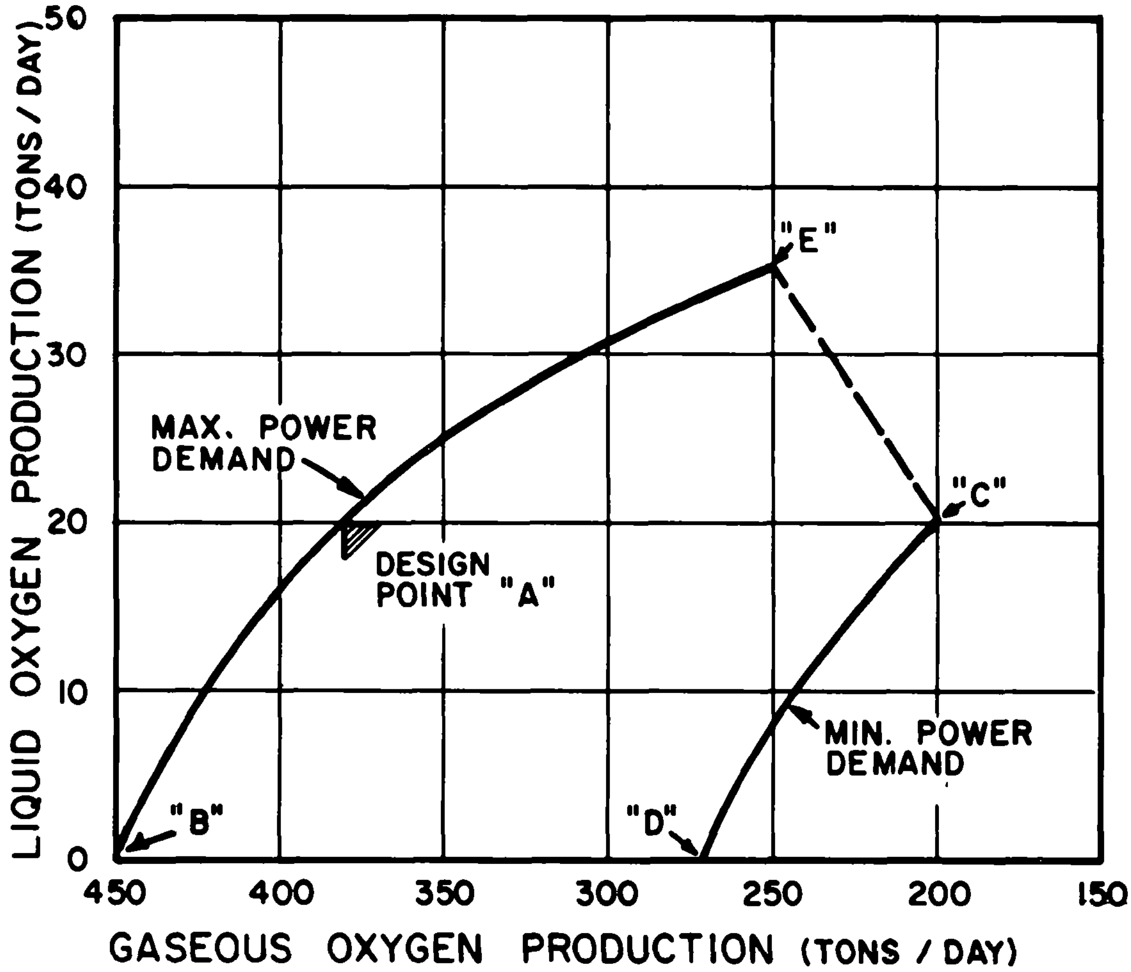

FIG. 5 LIQUID AND GASEOUS OXYGEN PRODUCTION

9. All pipes and equipment containing, processing or transporting liquid oxygen or nitrogen are very cold and must be well insulated otherwise ice will build up from the freezing of condensed atmospheric water vapor at any points not insulated.

10. Cryogenic gas oxygen will cost municipalities approximately $8 per ton (capital, operation and maintenance) at capacity production. Liquid oxygen costs approximately $35 per ton.

F. <u>P.S.A. Oxygen Generators</u> produce oxygen of 88 to 90 percent purity. PSA stands for Pressure Swing Absorption. Air at 60 to 90 psi is discharged into an absorption unit. Nitrogen is absorbed and oxygen is discharged from the unit to the oxygenator. After a few minutes, the pressure is released and the unit is flushed with air at low pressure and then with oxygen from another unit, and then receives air at high pressure to repeat the cycle. Three or four absorbtion units are used to produce oxygen so that oxygen is produced continuously. In comparison with cryogenic units, the oxygen is less pure, but the unit turn-down is limited only by the compressor capacity. At New Rochelle, we plan to use three compressors, one of which is a standby, so that we can reduce the oxygen production to 25 percent of the nominal capacity of 15 tons per day by operating one compressor at half capacity. These units are more economical in the smaller capacities. Because of their turn-down characteristics and the partial load under which most oxygen generators will work, the PSA units are more economical at higher oxygen capacities than would be expected by comparisons made for capacity production. We considered PSA generators to take some of the variable load at MCSA but decided against this on a cost basis.

The PSA generator using four absorption units uses 24 to 30 valves, most of which are operating every 2 to 5 minutes. The dependability of these valves is of paramount importance -- if one valve malfunctions, the entire unit shuts down. We have considered the possibility of providing an extra absorption unit which could be used to replace a malfunctioning unit. However, the interrelationship of the four units and the 24 to 30 valves make this difficult. Standby is provided from LOX storage.

G. Oxygen Storage is usually provided for liquid oxygen. Users, such as steel mills, with violent variations in demand, store oxygen gas at high pressures. This was not economical at MCSA.

1. Liquid oxygen is stored at a few inches of water pressure in highly insulated steel tanks. Approximately 5 days of storage is provided.
2. The heat gain into the storage tanks is met by evaporation of approximately 0.2 to 0.4 percent of the liquid oxygen per day. At MCSA, where 2000 tons of oxygen will

be stored, approximately 5 tons of LOX will be evaporated each day. This, if purchased, would cost approximately $175 per day, or approximately $63,000 per year.

3. LOX will be produced by the cryogenic plant when the full capacity of the plant is not required for gaseous oxygen. This LOX will be discharged to the LOX storage tanks along with a small amount of gaseous oxygen which will evaporate in the insulated pipe lines to counteract the heat gain in these lines. The cryogenic plant will have capacity not only to make up the LOX evaporated in storage and pipe lines but also capacity to make up for some of the LOX used in emergencies.
4. The LOX which evaporates in the storage tanks and pipe lines will be discharged into the GOX pipes feeding the oxygenation tanks.
5. LOX storage is provided for unforeseen failures of the cryogenic plant and also for part of the routine 10-day shutdown for maintenance, which occurs every two years.
6. The liquid oxygen must be evaporated and raised to ambient temperature before it can be used in the oxygenation tanks. Approximately 172 BTU is required to evaporate a pound of LOX and raise it to 70°F. Since it is desirable to be able to get GOX out of the storage tank on short notice, a fossil-fuel boiler would have to be maintained at operating temperature at all times. Heat could be provided by electric heaters. We are now

considering the use of final effluent to evaporate the LOX. Using 2600 gpm, the temperature drop in the water is estimated to be in the range of 15°F. This would be less than half a degree from the entire plant effluent. We have not decided if the danger of water freezing in the heat exchangers is critical.

7. The pumps which are used to move the LOX are critical. They must be kept as cold as the LOX. LOX could be moved through the evaporators and to the oxygenation tanks by maintaining a small pressure in the LOX storage tanks.
8. If oxygen is produced by PSA, the LOX storage must be refilled from time to time by purchased LOX which can be delivered in rail tank cars or trucks.
9. The oxygen industry is set up to deliver LOX so that there is no concern that they will be able to supply 400 tons of LOX per day to MCSA for indefinite periods, if this should ever become necessary.

H. Dangers using pure oxygen are not great.

1. GOX strongly supports combustion so that any materials, such as clothing, which may become saturated with oxygen will burn furiously. It is important, therefore, that precaution be taken until the oxygen is dissipated.
2. GOX explosion limits with explosive materials are the same as if the explosive materials were in air. No added danger.

3. If compressors and pipe lines are inside, then ventilation with 6 changes per hour should be used.

4. We doubt if explosive concentrations of materials in the raw wastewater will build up in the oxygenation tanks, but we have provided explosion meters and facilities for purging the gas space with air. We do this by valving the compressor suction so that air can be compressed and discharged through the spargers.

5. LOX will detonate if it comes in contact with hydrocarbons. Therefore, no asphalt should be used in the vicinity of LOX storage or pipe lines.

6. The LOX storage tanks should be surrounded by a dike which will hold the entire contents of the tanks. In the extremely unlikely chance that the LOX storage tank ruptures or leaks, the LOX will evaporate rapidly and be discharged into specific gravity of 32, compared with air at 29, so that it is only slightly heavier than air and will dissipate easily. In case of a large spill the GOX will be very cold and would have more of a tendency to stay on the ground and not mix.

For MCSA the use of the Unox Process is expected to save approximately 15 percent in project costs and annual costs.