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DEVELOPMENT OF FLOATING TYPE MECHANICAL AERATER, THE "FUJI AERATER" BY AXIAL-FLOW PUMP

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I. INTRODUCTION

Just as in the case of air pollution and such public hazards as garbage, noise and vibration, the economic and social backgrounds of the public hazard of water pollution are well known. Fuji Electric has had considerable experience with measurement, control and various other types of devices for water pollution control for water supply and sewage systems. As one of these, the company has developed the Fuji Aerater for aeration in sewage and industrial water pollution treatment processes. This article will explain the Fuji Aerater and discuss problems of its application in water pollution control.

As will be described later, there are two main aerater systems, the air dispersion system and the mechanical surface aeration system with the former being the most widely employed. Recently, however, considerable attention in this field has been directed to the latter floating type mechanical aerater using an axial-flow pump. The reasons for this are that the oxygen supply capability is improved and the amount of circulating water is greater because of the highly efficient axial-flow pump so that sufficient distribution of water is possible not only on the water tank surface but over the entire unit. The number of units can easily be altered in accordance with the changes in the water level and the load. The visual ugliness of the air dispersion system is avoided and the costs for such equipment as the pipe blower room can be avoided. The Fuji Aerater uses this mechanical surface aeration system and, in addition to water treatment by the activated sludge process, it is hoped that this aerater will find applications in the fish farming industry and other fields.

II. FUJI AERATER

1. Construction and Performance

The main components of the Fuji Aerater are the float, motor and axial-flow pump. The motor and the directly coupled axial-flow pump form a single unit with the main doughnut-type float.

The motor is a totally-enclosed fan-cooled outdoor-use induction motor. It is available in the condition such as in water droplets from water dispersion and also in rain water. The pump part consists of an impeller, diffuser and suction pipe. The pump impeller and the motor are coupled not by the usual coupling but by a common shaft. The float is made of steel plate with the inside filled with hard urethane foam. The entire unit is operated suspended on the water surface by means of the float. Therefore, there is a mooring eyebolt in the motor and the unit is moored with a cable.

Fig. 1 and *2* show the outer dimensions and an operating view respectively of the Fuji Aerater. The standard specifications are given in *Table 1.*

***Table 1* Standard specifications of Fuji Aerater**

	Model	VKX 55 A
Pump	Oxygen transfer capacity	9 kg·O_2/h
	Oxygen transfer efficiency	2 kg·O_2/kW·h
	Water circurating rate	870 m^3/h (14.5 m^3/min)
	Diameter of water dispersion	6 m
	Shaft horse power	4.5 kW
Motor	Model	MLA 1135 Z—62 B 0 A
	Output	5.5 kW
	No. of poles	6 poles
	Voltage	200 V
	Frequency	50 Hz
	Current	23.5 A
	Rotating speed	945 rpm
	Rule	JEC–37
	Rating	Continuous
	Insulation	Damp-proof E class insulation

Note : 1) The values of oxygen transfer capacity and efficiency are values resulting from experiments by the sodium sulfite deoxidation method in pure water at 20°C.
2) The water circulating rate, diameter of water dispersion and the shaft horsepower are all values for pure water at 20°C.
3) The water depth to be applied is 0.8 m or more. Performance is achieved by attaching the suction pipe in accordance with the depth.

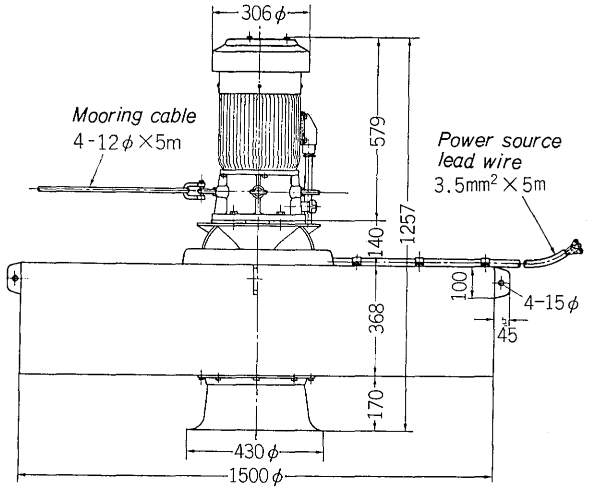

Fig. 1 Outline dimensions of VKX 55 A

Fig. 2 Fuji Aerator during operation

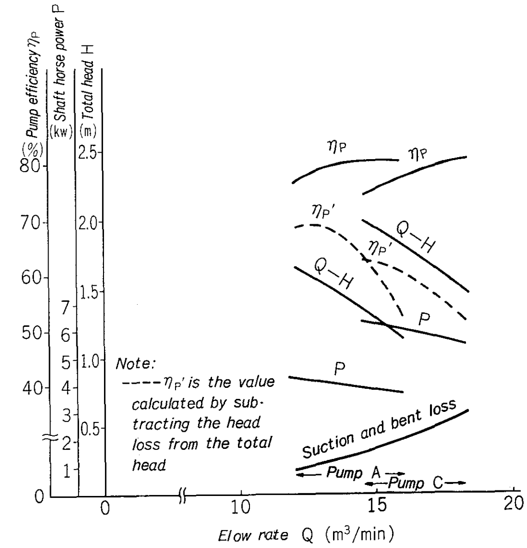

Fig. 3 Characteristics of pump A and pump C

2. Performance Test Results

The performance of the aerater is evaluated experimentally by the values of variation of the amount of oxygen dissolved in the water and this value divided by the shaft horsepower of the motor. These are called the oxygen transfer capacity and the oxygen transfer efficiency respectively. In the experiment, the operation performance in an acutal water tank was measured for various combinations of impellers and dispersers. Some of the measurement results are shown in *Table 2*.

When examining the measurement results, the maximum oxygen transfer efficiency was found to be at a disperser opening of about 50 mm for both the A and C impellers since the oxygen transfer capacity was even greater than the pump shaft horsepower although the latter was also large. The water circulation rate can be adjusted by changing the opening, but by increasing the pressure of the exhaust water above this value, the water dispersion distance, flying time and drop impact power to the water surface are also increased so that the oxygen transfer can be considered as increased. When observing the pump characteristics curve shown in *Fig. 3,* the important result that the oxygen transfer efficiency is a maximum near the point of maximum pump efficiency η_p is obtained. In this figure, the maximum η_p is $63\sim69\%$ but this is the value calculated by substracting the suction and delivery bent losses from the head. Since hydraulically, this loss is the pump work, η_p should be calculated from the head without subtracting the loss and this true η_p max. should be 81% for both the A and C pumps, which indicates pumps with excellent performance.

The air is dispersed in the air dispersion type aerater by a blower which will be described later. One of the reasons that this type of aerater is so widely used in the activated sludge process in spite of various disadvantages such as unattractive appearance, is that the oxygen transfer efficiency is better than in the conventional mechanical type aerater.

The oxygen transfer efficiency of the Fuji aerater is better than that of the air dispersion type at a performance above 2.0 kg · O_2/kW · h as was described previously. As a result, the pump efficiency is naturally increased and there are many cases when the optimum design depends on the relation between the decrease in flow and the increase in pressure by means of the opening. In the case of actual opera-

Table 2 **Tested results oxygen tranfer**

Pump type	Discharge opening (mm)	Oxygen transfer capacity (kg·O_2/h)	Oxygen transfer efficiency (kg·O_2/kW h)	Motor shaft horse-power (kW)	Water dispersion diameter (m)
A	125	4.37	1.37	3.45	4.5
A	78	5.91	1.49	3.96	5.0
A	47	6.49	1.52	4.28	6.0
C	125	10.93	1.97	5.55	6.0
C	78	12.65	2.09	6.05	6.5
C	47	13.39	2.15	6.20	6.8

Note : 1) The oxygen transfer values were for water at 20°C obtained by the DO meter and Winkler method of JIS K 0101.
2) The water tank volume was about 112 m³ and the oxygen transfer values were average values taken at two points each in the water tank.

tion in waste water, the brake horsepower can be considered as higher than that in pure water. The brake horsepower in pure water should be a value about 80% of the rated motor output and therefore, the previously mentioned standard specifications have been corrected on the basis of these test results.

III. APPLICATION OF FUJI AERATER IN WATER POLLUTION TREATMENT

Frankly speaking, the function of the aerater is to supply oxygen to the water but here, a quantitative description will be given whenever possible mainly concerning the use of the aerater in water pollution treatment.

1. Process of Industrial Water Pollution Treatment and Types of Aeration Equipment

The biochemical treatment of water pollution is divided into two types: the anaerobic process which does not need much oxygen and its opposite, the aerobic process. The latter is subdivided into the activated sludge method and the trickling filter process.

Aeration by the activated sludge method is an important process in waste water treatment. After decomposing and stabilizing the organic matter in the waste water by the propagation of aerobic microorganisms, it is removed by sedimentation. In the case of city sewage treatment which is one form of water pollution treatment, the process is as follows: sewage inflow→sand settling basin→first settling basin→aeration tank→second settling basin→disinfection→release to river. The main equipment in the aeration tank is the aeration equipment. In smallscale sewage treatment, the entire unit is very compact.

In the aeration process, several kinds of equipment are used: the fixed type mechanical aeration equipment in which an object like a turbine rotates on the water surface and creates a spray of water; air dispersion aeration equipment in which air bubbles are created from many small holes at a water depth of 3～4 m by a high pressure blower and float on the surface; and the turbine type aeration equipment in which large air bubbles are broken down and dispersed by a rotating impeller located near the air pipe which forms an opening at the water bottom. The dispersion aeration equipment is widelely used in sewage treatment, but recently, one type of mechanical aeration equipment, the float type aerator using an axial-flow pump which has an excellent efficiency hydraulically is being used in many cases. The advantages of this equipment are improved oxygen transfer efficiency, the possibility of circulation of water everywhere in the aeration tank because of the large amounts of circulating water, the simplicity of changing the water depth and number of equipment (or operating) units in accordance with BOD load, and the low equipment costs since distribution pipes and a blower room are not necessary.

2. Activated Sludge Treatment and Microorganisms

In the activated sludge process, organisms which can only be seen by a microscope such as bacteria, fungi, algae, etc. play an important role in the water purification. When contaminated water containing organic matter which is considered as standard from a general microbioengineering point of view as organic matter in waste water is aearated for several hours, the aerobic microorganisms increase and the organic material is adsorbed (or flocculated) by the microorganisms and the initially suspended materials form a soft flock which gradually increases in size from 1 mm to several mm. If the water containing this flock is kept in the settling basin, a clear supernatant is formed, and the flock forms a sediment at the bottom. If part of this sediment is then mixed with new contaminated water and this water is aerated, the groups of microorganisms in the flock sediment again adsorb the organic matter in the contaminated water and the sediment increases.

The activated sludge process is a repetition of the above. The sludge which becomes activated and is returned from the settling basin to the aeration tank is known as return sludge.

In this case, the microorganisms which adsorb the organic material in the water survive and propagate, and the organic matter in the water is reduced. In this process, about half of the adsorbed organic matter is decomposed and the remaining half of the organic matter is synthesized inside the microorganisms using the energy produced at this time. Finally, stabilized substances such as water or carbon dioxide are emitted to the exterior. In the activated

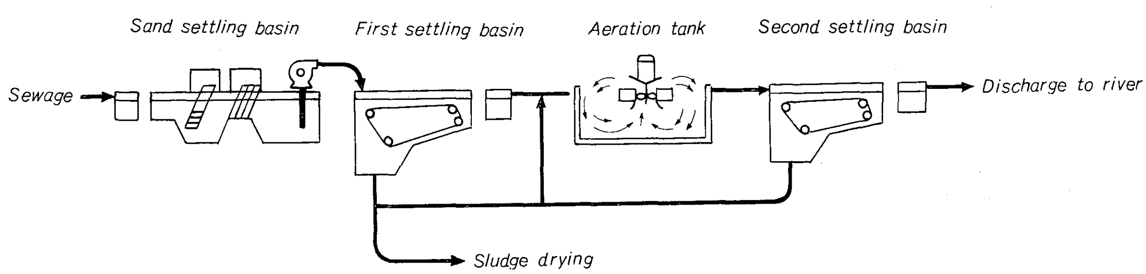

Fig. 4 Flowsheet of sewage treatment process

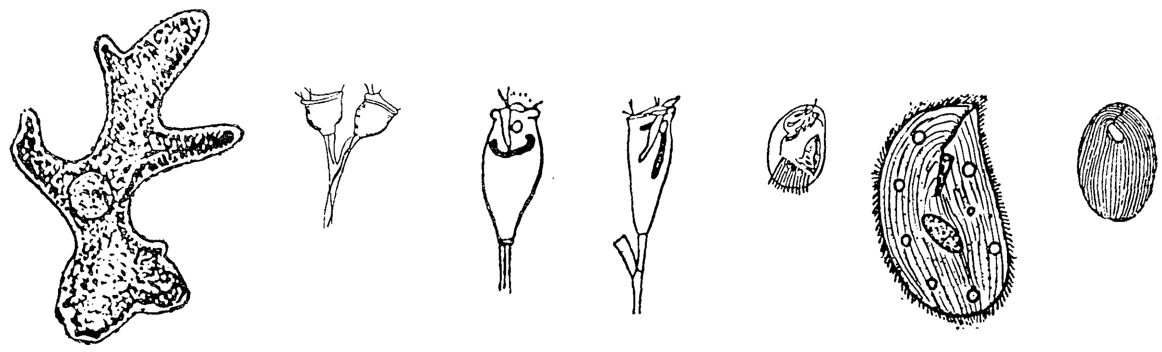

Fig. 5 Microorganisms in activated sludge

sludge process, 75—95% of the organic matter is removed from the usual waste water.

The types of microorganisms vary in accordance with the activated sludge and there is a difference between the groups of microorganisms appearing in activated sludge with a high purification power and that without such power. Those found in good condition activated sludge are known as activated sludge microorganisms, those in activated sludge of poor condition as non-activated sludge microorganisms and those in between as intermediate activated sludege microorganisms. They are shown in *Fig. 5*.

3. Relation Between Oxygen Transfer Capacity and Waste Water BOD

In order to decompose the organic matter in waste water by aerobic microorganisms in the activated sludge process, it is necessary that sufficient oxygen be continuously supplied to the waste water. In actual measurements in pure water, a 4.5 kW aerater supplied about 9 kg of oxygen per hour. By dividing this value by the shaft horesepower, an oxygen transfer efficiency of 2.0 kg $\cdot$ O_2/kW $\cdot$ h is obtained. This value is inevitably reduced if the dissolved oxygen (DO) which is normally zero in pure water becomes higher. The saturated DO of pure water is about 9.02 ppm at 20°C and atmospheric pressure but the oxygen transfer efficiency at this time is 0 even when the aerater is operating. In actual water pollution treatment, the value is generally low but because of the presence of DO and the physical differences between the pure and contaminated water, the load calculation in water pollution treatment is generally made for an oxygen transfer efficiency of about 1.0 kg $\cdot$ O_2/kW $\cdot$ h.

The amount of feces and urine per person per day is generally about 1 kg and the concentration of organisms is around 10,000 ppm. The biochemical oxygen demand (BOD), i.e. the amount of oxygen which must be supplied by the aerater is 0.01 kg O_2 per person per day. Since there is also waste organic matter other than feces and urine, the actual BOD for sewage treatment in a fixed area is about 0.05 kg O_2 per person per day. For example, for sewage treatment for a population of 10,000 persons, a 20 kW aerater is needed. For 100 million people, this figure becomes 200,000 kW. The feces and urine of all of the domestic animals in Japan are about the same degree as those of humans. In addition, almost all the general industrial water pollution treatment systems require the activated sludge process.

4. Aeration Tank Volume

As was described previously, the activated sludge process results in biological changes in microorganisms, food (organic matter) and oxygen in the water. The quantitative relation between the organic matter and the oxygen is related to the BOD and the oxygen transfer capacity. However, the relation between microorganisms and food also should have some connection in the desired treatment process. The amount of solid material in the activated sludge in the aeration tank is expressed as MLSS (Mixed Liquor Suspended Solid) and the concentration of microorganisms is expressed as MLSS mg/l. The ratio of food to the amount of microorganisms is connected to the sludge load (BOD kg/MLSS kg/day).

There are various modificatians of the activated sludge method but there is a desired relation between the method and the concentrations of organic matter and activated sludge which is obtained by means of a pilot plant or experience. *Table 3* shows typical examples of obtaining the load in the various modifications of the activated sludge process. If the MLSS mg/l and the sludge load BOD kg/MLSS kg/day are selected, the aeration tank volume can be calculated from the total amount of BOD per day. For example, if the MLSS is 2,000 mg/l (= 2,000 ppm) and the sludge load is 0.4 kg BOD/kg MLSS/day, the aeration tank volume V when 3,000 m^3/day of waste water with a BOD of 500 ppm are introduced is as follows since the BOD per day becomes 1,500 kg :

$$V=\frac{1{,}500\times 10^6}{2{,}000\times 0.4}=1{,}875{,}000\ l=1{,}875\ \mathrm{m}^3$$

i.e. the aeration tank volume is 1,875 m^3.

The method of determining the aeration tank volume from the sludge load and the MLSS concen-

Table 3 (a) **Dimensions of activated sludge process**

	BOD volume load (kg/m³/day)	Sludge load (kg BOD/kg MLSS/day)	M L S S (mg/l)	BOD (%)
Conventional process	0.5	0.2~0.5	1,000~2,500	95
Step aeration	0.8	〃	1,500~4,000	90~95
Contact stabilization process	1.1	0.5	2,000	85~90
Rapid aeration	1.6	2~5	300~800	60~75
Rapid block	2.4	0.5~1.0	2,500~5,000	90~95

Table 3 (b) **Dimensions of activated sludge process**

	BOD volume load (kg/m³/day)	Sludge load (kg BOD/kg MLSS/day)	M L S S (mg/l)	Aeration time
Total oxidation high class treatment	0.15~0.5	0.08 or less	3,000~7,000	24~72
Low load high class treatment	0.15~1.2	0.08~0.3	2,000~5,000	5~10
High load high class treatment	0.3 ~3.6	0.3 ~0.8	1,000~5,000	1~3
Middle class treatment	3.6 or above	0.8 or above	4,000 or above	0.5 or above

tration is comparatively new but there is also a method employing the volume load which is used in conjunction. The total amount of BOD introduced into the aeration tank per day divided by the aeration tank volume becomes 0.8 kg BOD/m³/day in the above example. When a 5.5 kW Fuji aerater is employed, from the total BOD, there will be 14 aeraters needed for an actual oxygen transfer capacity of 4.5 kg · O_2/h. When the water depth in the tank is 3.5 m, the receiving surface area of each aerater becomes 6.2 m × 6.2 m which is a suitable value in comparison with a water dispersion diameter of 6 m.

IV. CONCLUSION

In the development of the 5.5 kW Fuji aerater, it was clear from actual measurements of the pump and oxygen transfer characteristics that the maximum oxygen transfer efficiency was achieved when the opening was adjusted in such a way that the pump efficiency calculated from the head with the head loss subtracted was a maximum. There is a clear connection between the problems related to the aeration equipment using the axial-flow pump which has gained much attention recently and the previously elucidated theories and results of the activated sludge process. It is expected that this system will be widely utilized in water pollution treatment and other applications in the future.