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Indian Standard

REQUIREMENTS FOR BIOLOGICAL TREATMENT AND EQUIPMENT

PART II ACTIVATED SLUDGE PROCESS AND ITS MODIFICATIONS

UDC 628·356

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5 *September* 1982

Indian Standard

REQUIREMENTS FOR BIOLOGICAL TREATMENT AND EQUIPMENT

PART II ACTIVATED SLUDGE PROCESS AND ITS MODIFICATIONS

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Indian Standard

REQUIREMENTS FOR BIOLOGICAL TREATMENT AND EQUIPMENT

PART II ACTIVATED SLUDGE PROCESS AND ITS MODIFICATIONS

0. FOREWORD

0.1 This Indian Standard (Part II) was adopted by the Indian Standards Institution on 28 January 1982, after the draft finalized by the Public Health Engineering Equipment Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The biological waste water treatment processes remove non-settlable suspended and dissolved organic solids from a liquid stream and convert putrescible organic matter, which can support biological life, into stable and innocuous end products.

0.3 The activated sludge process is an aerobica l biological sewage treatment system for biological stabilization of organic matter. Synthesis of the waste organics results in build up of microbial mass in the system to maintain the proper food to micro-organism ratio to ensure optimum operation. Aerobic conditions must be maintained in the aeration tank. Microbial growth in the mixed liquor is maintained in the declining or endogenous phase to ensure good settling characteristics of biological flocs. The aeration tanks could be designed either as a plug flow system or as a complete mixed biological reactor.

0.3.1 The essential units of an activated sludge process are:

a) Primary settling tank,

b) Aeration tank,

c) Final settling tank,

d) Return sludge recycling equipment, and

e) Excess sludge removal equipment.

0.3.2 The commonly used pretreatment units are screens and grit channels. But they are not essential in all cases. The decision to adopt them in any particular waste water treatment system is governed by several factors among which are the quantity of floating material, inorganic grit and the concentration of suspended organic matters. However, in the case of extended aeration systems and where aerobic stabilization of excess activated sludge is practised, primary sedimentation unit is omitted.

0.3.3 Recommended loading rates for different activated sludge systems are given in Appendix A taking into consideration the tropical climatological conditions in the country.

0.4 This standard has been prepared in two parts. Part I deals with trickling filters, while Part II deals with activated sludge process and its modifications.

0.5 In the formulation of this standard, due weightage has been given to international coordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part II) covers the requirements for equipment and constructional requirements of conventional activated sludge process and its modifications, namely:

a) Conventional system,
b) High-rate system,
c) Extended aeration system, and
d) Contact stabilization system.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Activated Sludge — Mass of micro-organisms, flocculated and easily settlable, metabolizing organic material in a waste in activated sludge aeration tank. This is obtained in settling tanks after aeration and is returned to the aeration tank for maintaining adequate concentration of micro-organisms.

*Rules for rounding off numerical values (*revised*).

2.2 Activated Sludge Process — A biological sewage treatment process in which a mixture of sewage and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated sewage (mixed liquor) by sedimentation, and allowed to go waste or returned to the process as needed. The treated sewage overflows the weir of the settling tank in which separation from the sludge takes place.

2.3 Aerated Lagoons or Ponds — A natural or artificial waste water treatment pond in which mechanical or diffused-air aeration is used to supplement the oxygen supply.

2.4 Contact Stabilization Process — A modification of the activated sludge process in which raw waste water is aerated with a high concentration of activated sludge for a short period, usually less than 60 min, to obtain BOD removal by absorption. The solids are subsequently removed by sedimentation and transferred to a stabilization tank where aeration is continued further to oxidize and condition them before their reintroduction to the raw waste water flow.

2.5 Conventional Activated Sludge Process — An aerobic biological treatment system in which the pre-settled sewage is aerated with return sludge in an aeration tank for a sufficient period of time to produce a well settling sludge and clarified supernatant in the secondary settling tank.

2.6 Diffused Air Aeration — Aeration produced in liquids by air passed through a diffuser.

2.7 Extended Aeration — A modification of the conventional sludge process which provides for aerobic sludge digestion within the aeration system. The concept envisages stabilization of organic matter under aerobic conditions and disposal of the end products into the air as gases and with the plant effluent as finely divided suspended matter and soluble matter.

2.8 High Rate System — An activated sludge process which is operated at a high rate of loading and short aeration period resulting in dispersed growth of micro-organisms leading to a poorly clarified effluent and a partial treatment of sewage.

2.9 Activated Sludge Loading — The mass (in kg) of biochemical oxygen demand (BOD) in the applied liquid per unit volume of aeration capacity or per unit mass (in kg) activated sludge per day.

2.10 Mixed Liquor — A mixture of activated sludge and sewage in the aeration tank.

2.11 Mixed Liquor Suspended Solids (MLSS) — Suspended solids in the mixed liquor at an instant of time taken as an approximate measure of microbial mass concentration in the biological reactor.

2.12 Mixed Liquor Volatile Suspended Solids (MLVSS) — The volatile fraction of the MLSS, considered to be a better representation of microbial mass.

2.13 Mechanical or Surface Aeration

a) The mixing, by mechanical means, of sewage and activated sludge in the aeration tank of the activated sludge process, to bring fresh surfaces of liquid into contact with the atmosphere.

b) The introduction of atmospheric oxygen into a liquid by the mechanical action of paddle or spray mechanisms.

2.14 Permeability Rating — The number of cubic metres per minute of free air which will pass through one square metre of dry diffuser surface at 50 mm differential pressure under dry conditions at a temperature of 20°C.

2.15 Return Sludge — Activated sludge returned from the secondary settling tank/clarifier to the aeration tank directly or after reaeration.

2.16 Sludge Retention Time (SRT) — Time for which flocculated micro-organisms are under aeration is referred to as sludge retention time. It is the ratio of biological solids in the aeration tank to the solids wasted from the system per day. SRT is theoretically correlated with the organic loading. When Food/Micro-organisms (F/M) is high, SRT is low and *vice-versa.*

2.17 Waste or Excess Sludge — Excess activated sludge resulting from the growth of microbial mass in the aeration tank, wasted from the underflow or secondary settling tank.

3. MATERIALS AND CONSTRUCTION PRACTICES

3.1 The materials used for component parts and the methods of construction to be adopted shall be as given in Table 1.

4. CONSTRUCTION

4.1 Aeration Tank — The volume of the aeration tank is worked out on the basis of loading rates and the VSS to be maintained in the system as per Appendix A.

4.1.1 For plants treating 400 m^3/h, the total aeration tank volume required shall be divided among two or more units capable of independent operation.

4.1.2 Two types of aeration tanks are built depending on the type of aeration, namely, (a) diffused aeration tanks, and (b) mechanical or surface aeration tanks.

4.1.3 Diffused aeration tanks are again subdivided into three types, namely, (a) ridge and furrow tanks, (b) spiral flow tanks, and (c) combination of the two.

4.1.4 The ratio of length to width shall generally exceed 5 to 1 in order to reduce short circuiting. In small plants, tanks may be built as straight-through units. In large plants, they may be built as continuous flow channels with longitudinal around-the-end baffles.

4.1.5 Liquid depth in diffuser and mechanically aerated tanks shall be not less than 3 m and not more than 5 m. Liquid depth for normal surface aerator having power less than 20 kW without draft tube shall not exceed 3·0 m.

4.1.6 For diffused aeration, two or three transverse baffles spaced out not less than 15 m apart may be provided in each aeration tank to reduce short circuiting.

4.1.7 Point velocities in aeration channels shall be more than 0·15 m/s to avoid settling of sludge. Deflectors at the surface and fillets at the bottom and rounding of corners may be provided to help in maintaining circulation and to prevent formation of unaerated pockets and short circuiting.

4.1.8 The effective diffuser area provided shall not be less than 5 percent or more than 15 percent of the tank bottom area for spiral flow tanks. For the ridge and furrow tanks it shall not be less than 15 percent nor more than 25 percent of the tank bottom area.

4.1.9 A minimum free board of 0·6 m is recommended.

4.1.10 Inlet parts may or may not be submerged. But the outlet should preferably be over a weir.

4.1.11 Inlets and outlets shall be suitably equipped with valves, gates, stop planks, weirs and other devices to permit controlling the flow to any unit and to maintain a reasonably constant water level. The hydraulic properties of the system shall permit the maximum instantaneous hydraulic load to be carried with any single unit of service.

TABLE 1 MATERIALS AND METHODS OF CONSTRUCTION OF AERATION CHAMBER

(*Clause* 3.1)

SL No.	PARTICULAR	MATERIAL	REF TO INDIAN STANDARD
i)	Civil works	a) Reinforced or plain concrete	IS : 456-1978[1] IS : 3370 (Part I)-1965[2] IS : 3370 (Part II)-1965[3] IS : 3370 (Part III)-1967[4] IS : 3370 (Part IV)-1967[5]
		b) Brick masonry	IS : 2212-1962[6]
		c) Stone masonry	IS : 1597 (Part I)-1967[7] IS : 1597 (Part II)-1967[8]
ii)	Motors, starters, time switches and electrode switches	—	IS : 325-1978[9] IS : 996-1964[10] IS : 1766-1973[11] IS : 1822-1967[12]
iii)	Turn table	High grade cast iron	IS : 210-1978[13]
iv)	Gears	a) Steel	IS : 1570-1961[14]
		b) Aluminium bronze	IS : 305-1961[15]
v)	Cover for main gear	a) Epoxy coated mild steel	IS : 226-1975[16]
		b) Cast iron	IS : 210-1978[13]
vi)	Base for main gear	Cast iron	IS : 210-1978[13]
vii)	Worm gear housing	Cast iron	IS : 210-1978[13]

[1]Code of practice for plain and reinforced concrete (*third revision*).

[2]Code of practice for concrete structures for the storage of liquids: Part I General requirements.

[3]Code of practice for concrete structures for the storage of liquids: Part II Reinforced concrete structures.

[4]Code of practice for concrete structures for the storage of liquids: Part III Prestressed concrete structures.

[5]Code of practice for concrete structures for the storage of liquids: Part IV Design tables.

[6]Code of practice for brickwork.

[7]Code of practice for construction of stone masonry: Part I Rubble stone masonry.

[8]Code of practice for construction of stone masonry: Part II Ashlar masonry.

[9]Specification for three-phase induction motors (*fourth revision*).

[10]Specification for single-phase small ac and universal electric motors (*revised*).

[11]Specification for time switches (*first revision*).

[12]Specification for ac motor starters of voltage not exceeding 1 000 volts (*first revision*).

[13]Specification for grey iron castings (*third revision*).

[14]Schedules for wrought steels for general engineering purposes.

[15]Specification for aluminium bronze ingots and castings (*revised*).

[16]Specification for structural steel (standard quality) (*fifth revision*).

(*Continued*)

TABLE 1 MATERIALS AND METHODS OF CONSTRUCTION OF AERATION CHAMBER — *Contd*

SL No.	PARTICULAR	MATERIAL	REF TO INDIAN STANDARD
viii)	Bearing balls	High carbon steel	IS : 2898-1976[17]
ix)	Weirs	Mild steel and plastic	IS : 226-1975[16]
x)	Feed well	Mild steel	IS : 226-1975[16]
xi)	Gauge	Mild steel	IS : 226-1975[16]
xii)	Deflector	Plastic	—
xiii)	Diffusers	Plastic	—
		Ceramics	—
xiv)	Gates	Cast iron, steel	IS : 3042-1965[18] IS : 226-1975[16]
xv)	Scrapers (fabricated sheets)	a) Mild steel	IS : 226-1975[16]
		b) Alloy steel	IS : 1570-1961[19]
xvi)	Shaft	Cold finished steel	IS : 1570-1961[19]
xvii)	Floats	Plastic (polyethylene, PVC, glass fibre reinforced polyester)	— —
xviii)	Channels	Steel	IS : 3954-1966[20]

[16]Specification for structural steel (standard quality) (*fifth revision*).
[17]Specification for steel balls for rolling bearings (*first revision*).
[18]Specification for single faced sluice gates (200 to 1 200 mm size).
[19]Schedules for wrought steels for general engineering purposes.
[20]Specification for hot rolled steel channel sections for general engineering purposes.

4.1.12 Channels and pipes carrying liquid with solids in suspension, to and from the areation tank, shall be designed to maintain a minimum velocity of 0·6 m/s.

4.1.13 The difference in water surface between primary settling tank and aeration tank and final, settling tank shall be at least 0·15 m at maximum rate of flow after accounting for the frictional losses between the two units.

4.1.14 Measuring devices shall be installed in such a way that inflow to the aeration chamber can be measured. Return sludge shall also be measured.

4.2 Aeration Equipment

4.2.1 The function of the equipment is to provide aeration and mixing. Three methods stated below are commonly employed (*see* Appendix B):

a) Compressed air diffused aeration,

b) Mechanical (including surface system) aeration, and

c) Compressed air with mechanical aeration.

4.2.2 General sketches of various types of aerators are shown in Fig. 1 to 6. The capacity of the aeration equipment for transfer of oxygen should be related to the amount of BOD removed and the quantity of VSS maintained in the system.

4.2.3 Supporting data shall be provided by the designer to show that the equipment is capable of transferring the required amount of oxygen in aeration tank similar to the one adopted in the design, either in the form of oxygen transfer characteristic curves or long term performance data of plants operated under similar conditions.

4.2.4 The aeration equipment shall maintain at least 1 mg/litre of dissolved oxygen under all the conditions of loading in the aeration zone. A minimum of 1·5 mg/litre should be maintained in extended aeration activated sludge process.

4.2.5 The aeration equipment shall be able to meet the recommendartions given in **4.1.7**.

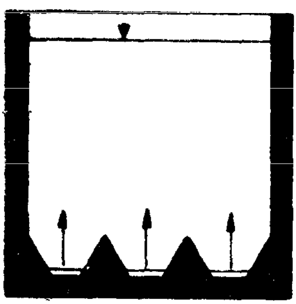

FIG. 1 DIFFUSED AIR ACTIVATED-SLUDGE SYSTEMS — RIDGE AND FURROWS

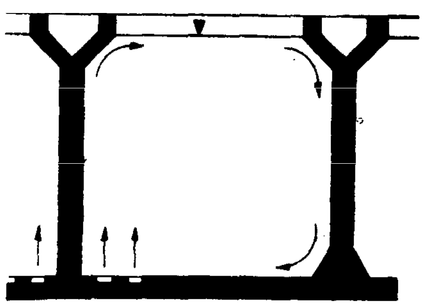

FIG. 2 DIFFUSED AIR ACTIVATED SLUDGE SYSTEM — SPIRAL FLOW

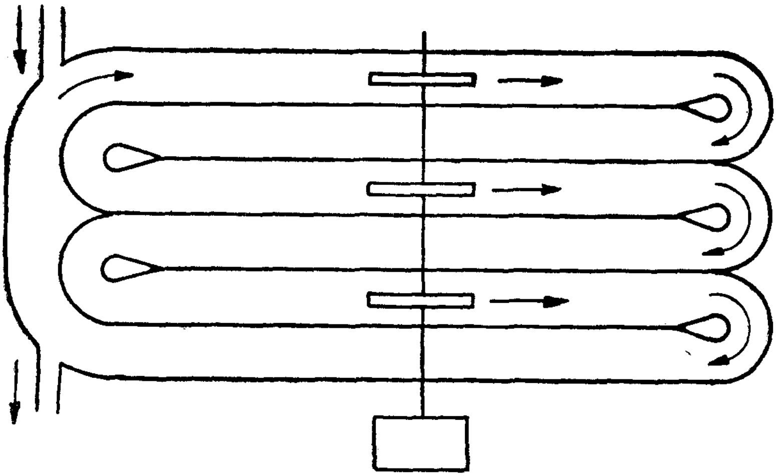

FIG. 3 MECHANICAL ACTIVATED-SLUDGE SYSTEM

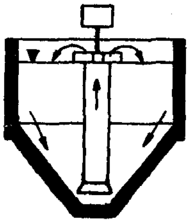

FIG. 4 SURFACE SYSTEM — IMPELLER DRAFT TUBE TYPE ACTIVATED SLUDGE TANK

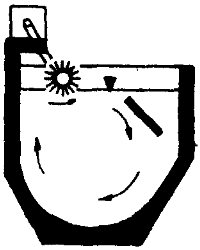

FIG. 5 SURFACE SYSTEM-BRUSH ACTIVATED SLUDGE TANK

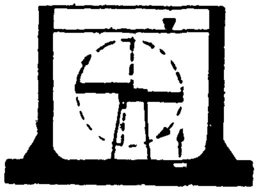

FIG. 6 PADDLE-WHEEL ACTIVATED-SLUDGE TANK WITH DIFFUSED AIR

4.2.6 In the case of compressed air aeration the air diffusion system shall be capable of delivering 1·5 times the design requirement.

4.2.7 Porous ceramic diffusers shall have a permeability rating of 12 to 24. The corresponding pore diameter shall be 0·3 mm and 0·5 mm respectively. A diffuser made of some other material should have a comparable permeability.

4.2.8 In the case of air supply to porous diffuser, suitable cleaning equipment shall be provided.

4.2.9 The air-blowers may be positive displacement type or centrifugal type. Reciprocating piston compressors are not suitable. For large capacities, centrifugal blowers should be preferred, as discharge can be varied by throttling.

4.2.10 All air mains shall be so located as to prevent back syphonage of liquid in case of air pressure failure.

4.2.11 Mechanical aerators shall be in multiple units, preferably of equal capacity. The oxygen transfer capacity under standard conditions should be specified. A standby aeration unit is also recommended.

4.2.12 The pressure at the blower shall be not less than 1·25 times the head of sewage in the aeration tank. For a 5 m depth of liquid in the aeration tank, the delivery pressure of the blower shall be 0·04 to 0·065 MPa.

4.2.13 In the case of fan/cone type aerator, the conical body and the fan blades shall be made of mild steel plate (*see* IS : 226-1975*) not less than 3 mm thick. The fan blades, the vertical cylindrical draft ring, forming part of the aerator and the air-lock ring, if provided shall be made of not less than 5 mm thick plate of the same material.

4.2.13.1 Fan blades shall be of either mild steel or alloy steel. The fan blades shall be correctly shaped and welded properly to the fan body, so as to withstand the forces generated by the resistance of the liquid, when the fan is switched on, with the top of the fan (excluding the fan blades) just immersed under the liquid in which it is to work.

4.2.13.2 The suspension ring shall be made of mild steel flat bar and shall be securely welded to the fan blades.

4.2.14 The motors used for driving surface aerators, shall be totally enclosed fan cooled squirrel cage induction motors conforming to IS : 325-1978†. In case motors are to be mounted vertically, a canopy should be provided. The starting characteristics of the motor should suit the aerators, and special requirements, if any, should be ascertained from the aerator manufacturers.

4.2.15 Starters shall be direct-on-line or star-delta oil immersed type in accordance with the requirements of the Electric Supply Undertaking.

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*Specification for structural steel (standard quality) (*fifth revision*).

†Specification for three-phase inductions motors (*fourth revision*).

They should have under-voltage and thermal overload relays, and push button operated stopping arrangements.

4.3 Final Settling Tank — The final settling tank shall conform to IS : 10261-1982*.

4.4 Return Sludge Recycling Equipment

4.4.1 The capacity of the return sludge recycling system shall be based on the MLSS concentration to be maintained in the aeration tank and the expected suspended solid concentration in the return sludge.

4.4.2 The return sludge pumping capacity shall be equal to 100 percent of the amount computed to satisfy **4.4.1**. In addition, adequate standby shall be provided.

4.4.3 A positive suction shall be provided.

4.4.4 The suction and delivery lines shall be at least 100 mm in diameter. A minimum velocity of 0·6 m/s shall be maintained to prevent sedimentation.

4.5 Excess Sludge Removal — Waste activated sludge may be discharged to primary tanks, concentration tanks, aerobic or anaerobic digestion tanks, or any practicable units for further treatment. In the case of extended aeration systems, it can be directly dried on sludge drying beds with or without prior treatment.

*Requirements for settling tank (Clarifier equipment) for waste water treatment.

APPENDIX A

(*Clauses* 0.3.3 *and* 4.1)

RECOMMENDED LOADING RATES FOR DIFFERENT ACTIVATED SLUDGE TREATMENT SYSTEMS

Sl No.	*Type of System*	*Loading*		*MLSS (mg/litre) in Reactor*	*Sludge Retention Time (SRT), Days*	*Air Requirement per kg BOD_5 M^3*
		$\frac{\text{kg } BOD_5 \text{ Removed}}{\text{kg MLSS}}$ per day	$\frac{\text{kg } BOD_5 \text{ Removed}}{\text{kg MLVSS}}$ per day			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Conventional A.S.P.	0·3-0·7	0·35-0·85	1 500-3 000	3-15	40 to 100
ii)	High rate A.S.P.	1·5-2·0	1·90-2·5	500-1 000	Less than 3	25 to 50
iii)	Extended aeration A.S.P. (completely mixed)	0·1-0·2	0·2-0·4	3 000-8 000	More than 10 preferably 20 to 30	100 to 135
iv)	Contact stabilization A.S.P.	0·4-0·8	0·5-1·0	a) 1 000-3 000 b) 3 000-6 000	3-15	50 to 75

$$SRT = \frac{1}{YU\ kd}$$

where

U = process loading, kg BOD removed/kg VSS/day;
Y = yield coefficient, mg VSS/mg BOD removed; and
kd = specific micro-organism decay rate, per day.

NOTE — In places where winter temperature falls below 15°C, the loading rates should be increased for an extended period of time, during that period.

APPENDIX B

(*Clause* 4.2.1)

TYPES OF AERATORS COMMONLY EMPLOYED

B-1. IMPINGEMENT AERATOR (FIG. 7)

B-1.1 The impingement aerator employs a water stream air lifted from the aeration tanks as a shearing device for air bubbles discharged from a large orifice. The control variables are the impingement liquor flow, air flow and the location of the water nozzle relative to the air orifice. The necessity of air filter is usually eliminated.

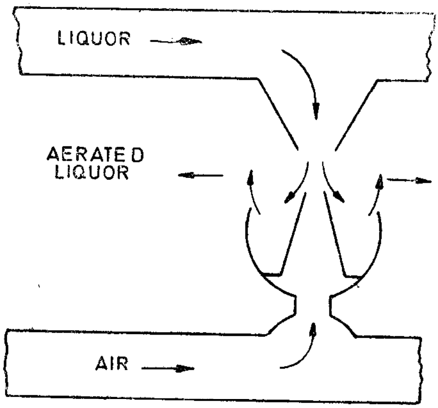

FIG. 7 IMPINGER

B-2. SPARGERS (FIG. 8)

B-2.1 The sparger is a controlled air release device consisting of a specially designed, cross-ribbed casting arrangement to release air through a cluster of four high velocity short tube orifices in a concentrated, properly located air pattern. A unique turbulence develops as the concentrated air lift column above each sparger reacts with the surrounding liquor, and a short distance above the orifice cluster, the chain line larger bubbles are broken into a cloud of small bubbles.

B-3. MECHANICAL OR SURFACE AERATORS

B-3.1 The mechanical aerators are of the following three types:

a) An impeller which induces flow across the blades resulting in a vortex action and a surface local spray (surface aerator),

b) A surface impeller with draft tube from which the liquid is drawn and spread over the surface, and

c) Vortair entrainment aerator.

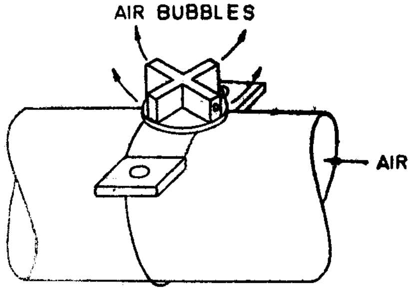

FIG. 8 SPARGER

B-3.1.1 *Surface Aerator* — The surface aerator consists of a circular, flat plate with vertical/horizontal blades extending radially from the periphery of the plate towards the corner. The plate is rotated in a horizontal plane a short distance below the normal water surface. When the aerator is started in operation, the top of the plate is cleared of water, and a hydraulic jump is formed and air is entrained by the blades of the turbine.

B-3.1.2 *Impeller Draft Tube Type Aerator* — This aerator comprises an open ended conical shell formed from steel plate to the inner face of which are attached a number of specially shaped blades. The inner edges of the blades are welded to a steel ring positioned well clear of liquid moment and into the ring of the weatherproof gearhead. The upper tip of the cone is located several centimetres above water level and below the cone is a stationary uptake tube. The seal is formed by the spigot end of the uptake tube entering an annular air lock chamber in the inlet skirt of the revolving cone.

The uptake tube is positioned in the middle of the aeration tank and is usually 600 to 900 mm in diameter, the lower end terminating in a bell mouth which is supported several centimetres above the floor of the channel by means of three adjustable feet.

B-3.1.3 *Vortair Entrainment Aerator* — This device is for the use of a specially designed turbine located a short distance below the liquid surface. The oxygen entrainment from atmospheric air takes place due to two basic hydraulic phenomena that occur when the turbine is rotated at a proper speed. First the radial discharge from the turbine issuing slightly below the normal liquid level produces a peripheral hydraulic jump. Secondly, a hydrodynamic condition is set up inside the turbine, so that air is drawn into the flow issuing from the turbine. Under proper submergence conditions, for any given turbine diameters and speed, the top plate of the turbine becomes entirely free of liquid. Under these conditions, air is sucked down first from the top plate of the turbine due to region of low pressure behind each of the radial blades. The high velocity water issuing radially from the turbine entrains air from the masses of air behind each of the radial blades, and thus the flow issuing is full of air bubbles.

(*Continued from page* 2)

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SHRI S. BHOOTALINGAM	Kerala State Board for Prevention and Control of Water Pollution, Trivandrum
SHRI J. D. JOYSINGH (*Alternate*)	
SHRI O. P. BISHNOI	Uttar Pradesh Jal Nigam, Lucknow
SHRI S. S. SRIVASTAVA (*Alternate*)	
CHAIRMAN	Haryana State Board for Prevention and Control of Water Pollution, Chandigarh
MEMBER-SECRETARY (*Alternate*)	
CHIEF ENGINEER (SEWERAGE)	Municipal Corporation of Greater Bombay, Bombay
DEPUTY CHIEF ENGINEER (SEWERAGE) (*Alternate*)	
SHRI M. M. DATTA	Central Public Health and Environmental Engineering Organization, New Delhi
DR I. RADHAKRISHNAN (*Alternate*)	
SHRI M. Y. MADAN	The Hindustan Construction Co Ltd, Bombay
SHRI C. E. S. RAO (*Alternate*)	
PROF B. L. MAHABAL	Victoria Jubliee Technical Institute, Bombay
SHRI R. V. S. MURTHY (*Alternate*)	
SHRI U. C. MANKAD	Geo-Miller & Co Pvt Ltd, New Delhi
SHRI D. K. CHAUDHURY (*Alternate*)	
MEMBER-SECRETARY	Central Board for the Prevention and Control of Water Pollution, New Delhi
DR K. R. RANGANATHAN (*Alternate*)	

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Members	*Representing*
SHRI D. V. S. MURTHY	M. P. State Prevention and Control of Water Pollution Board, Bhopal
SHRI S. S. NAIK	Hydraulic & General Engineers Pvt Ltd, Bombay
SHRI D. R. KENKRE (*Alternate*)	
SHRI R. NATARAJAN	Hindustan Dorr-Oliver Ltd, Bombay
SHRI B. M. RAHUL (*Alternate*)	
DR N. RAJASEKHARAN	Pennwalt India Limited, Bombay
DR K. RUDRAPPA	Engineers India Limited, New Delhi
SHRI R. N. TIWARI (*Alternate*)	
SHRI V. SATYAMURTHI	EIMCO-KCP Ltd, Madras
SHRI T. SUBRAHMANYAM (*Alternate*)	
SHRI C. L. SASTRI	Candy Filters (India) Ltd, Bombay
SHRI D. B. PARMAR (*Alternate*)	
PROF S. SUBHA RAO	All India Institute of Hygiene & Public Health, Calcutta
SHRI A. V. RAO (*Alternate*)	

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	Unit	Symbol	Definition
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2