Jet Floccu-Clarifiers: Appropriate Technology for Water Treatment in India

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ABSTRACT

Sustained supply of safe and potable water is of paramount significance in promotion of health and well being of the people. It is commonly observed that the mechanical components forming part of Flash Mixers, Flocculators and Clarifiers become soon non-functional. There are number of examples where these have served not more than 12 months from the plant commissioning. In view of this, the paper emphasizes the need to develop water treatment plant designs that minimizes the component of mechanical equipment as much as possible. This paper presents the designs of Floccu-Clarifier (FC) (Clariflocculator in established sense) based on Jet Flocculation Systems, which eliminate altogether the mechanical components in pretreatment of water prior to filtration.. The shape of the unit may be circular or rectangular, depending on the size of the plant. High Rate Flat Bottom FC (Sludge Blanket Type) designs for small capacity units (up to 5 MLD) or large capacity units (above 5 MLD) are suggested. All the designs are illustrated by typical examples. Preliminary observations on a small circular unit, modified by incorporating the jet flocculation system, are quite encouraging. The new designs utilizing Jet Flocculation System may be advantageously used for sustained satisfactory service.

INTRODUCTION

Sustained supply of safe and potable water is of paramount significance in promotion of health and well being of the people. Waters from surface sources such as Rivers, Natural Lakes and Impounding Reservoirs are generally polluted and not readily usable for drinking. Water Treatment Plants (WTP), and more importantly the pretreatment by flocculation & settling before filtration and subsequent disinfection, plays a crucial role in meeting its goal in a sustainable manner. These units must fulfill the following objectives :

(i) Irrespective of the raw water turbidity, the settled water turbidity should be as low as possible and not above 20 NTU, in any case), to limit the load on the Filters.

(ii) The quantity of sludge produced should be as low as possible and preferably below 1%, to minimize unnecessary wastage of water and also the resultant waste sludge treatment.

(iii) It should involve minimum recurring expenditure on account of energy and chemicals.

(iv) WTPs should be simple for construction, operation and maintenance.

The Author of the paper has visited several WTPs throughout the length and breadth of the country. It is commonly observed that the mechanical components forming part of Flash Mixers, Flocculators and Clarifiers become soon non-functional. There are number of examples where these have served not even 12 months from the date of plant commissioning. Even today, there are numerous examples where mechanical equipments like filter rate controllers continue to be unnecessarily or superfluously incorporated, especially on the backdrop of better non-mechanical and more efficient options like Declining Rate Filters or Variable Head Constant (nearly constant) Rate Filters.

In this context, it will be interest to cite the findings of an Expert Committee appointed by the Water Supply & Sanitation Department, Maharashtra State, in the year 2001, to carry out Rapid Performance Audit (RPA) of the Water Works of Municipal Corporations and Class 'A' Municipal Councils in Maharashtra. The Committee has made following observations (Rotkar 2001) that :

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- In many Water Works, the mechanical equipment initially provided for dosing the chemical (usually alum) was non-functional. Crude practices followed at times resulted in over or under-dosing. Over-dosing (3-4 times than necessary) resulted in lowering of pH and corrosion of ironwork in contact with water.
- In majority of works, the equipment like flash mixers, flocculators and scraper bridges, which are important from the point of view of water treatment, have not been functioning since years.

Since the failure of mechanical equipments in WTPs fail to achieve the desired performance, author feels that, minimization of mechanical equipment in the WTPs as much as possible, can contribute significantly in developing appropriate systems. In this paper the author aims to present the evolution of various additional designs of flocculation and clarification units with the least involvement of mechanical components.

The author has utilized an opportunity to deploy his new technique for one non-functional clarifier unit in Maharashtra. The detailed performance evaluation of the unit is underway. However, preliminary observations on the performance of this unit are quite encouraging.

About the Change in Unit Designation

The author specially likes to focus attention of the readers to the proposed change of nomenclature of combined flocculation & clarification unit. He prefers to designate the popularly known 'Clari-Flocculator' as 'Floccu-Clarifier' (FC). This is principally because of two reasons, namely :

(i) The process of flocculation is carried out before clarification.

(ii) Besides the sequence of operations, the process of flocculation is a pre-requisite operation that is of paramount significance for effective clarification.

LITERATURE REVIEW

Development towards minimizing or eliminating mechanical components for flocculation and settling in water treatment is not new in respect of package and small treatment plants. Candy types of Hopper Bottom Sludge Blanket Clarifiers (HBSBC) continue to be used since the last more than hundred years all over the world. Manifestations and modifications of HBSBC have been suggested both for package plants and small size plants (Dhabadgaonkar 1978, 1979).

Dhabadgaonkar et al (1994) presented a new concept in flocculation to completely eliminate the need of mechanical equipment. This approach utilizes the kinetic energy of incoming raw water to maintain the requisite velocity gradient through the helicoidal flow pattern in a conically shaped flocculator. A study by Bhagwatkar (1993-1994) at Ralegaon (District: Yavatmal) established the applicability of the process in the field. Observing the success of the new concept in small plants, Dhabadgaonkar (1993) anticipated and advocated the application of the concept to large-size plants also. Subsequently, Dhabadgaonkar & Sahoo (1997) extended the application of the concept to modify the design of Hopper Bottom Sludge Blanket Clarifiers, which posed certain operational problems.

Though the concept and its manifestations were presented much earlier as stated above, the opportunity to examine the field performance came much later. The flocculation part of the WTP at Pandharkawada (District: Yavatmal), was specially designed and constructed on the principles of jet induced flocculation. Besides its own evaluation, this study also included comparison of performance of this plant with the conventional WTP, using raw water from the same source. This study clearly demonstrated the superiority of the approach over the conventional (Gokhale et al 1998).

The reluctance to adopt hopper bottom tanks, especially for large capacity works (>5 MLD) was seen to be due to following reasons:

- High cost of deep excavations, especially in hard / rocky strata.
- High construction cost compared to conventional Clariflocculator.

Due to above-mentioned disadvantages the development of flat bottom tanks has taken place. The typical examples include (a) Flat Bottom Sludge Blanket Clarifier [Ives and Hale 1968] and (b) Degremont Pulsator Clarifier.

FLOCCU-CLARIFIER DEVELOPMENT

The Floccu-Clarifiers (FC) embodies the advantageous features of Jet Flocculation System and Flat Bottom Tanks.

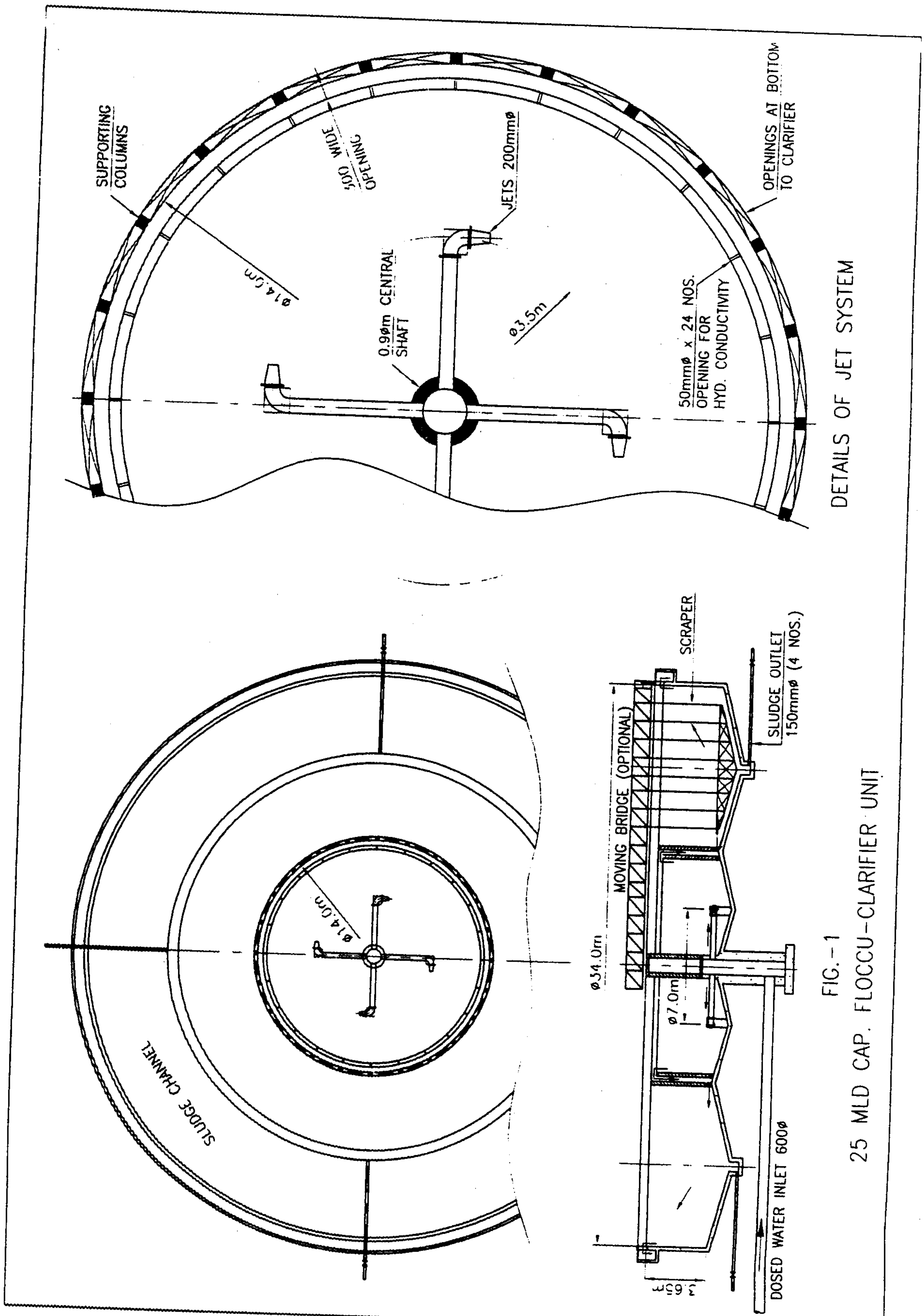

FIG.-1
25 MLD CAP. FLOCCU-CLARIFIER UNIT

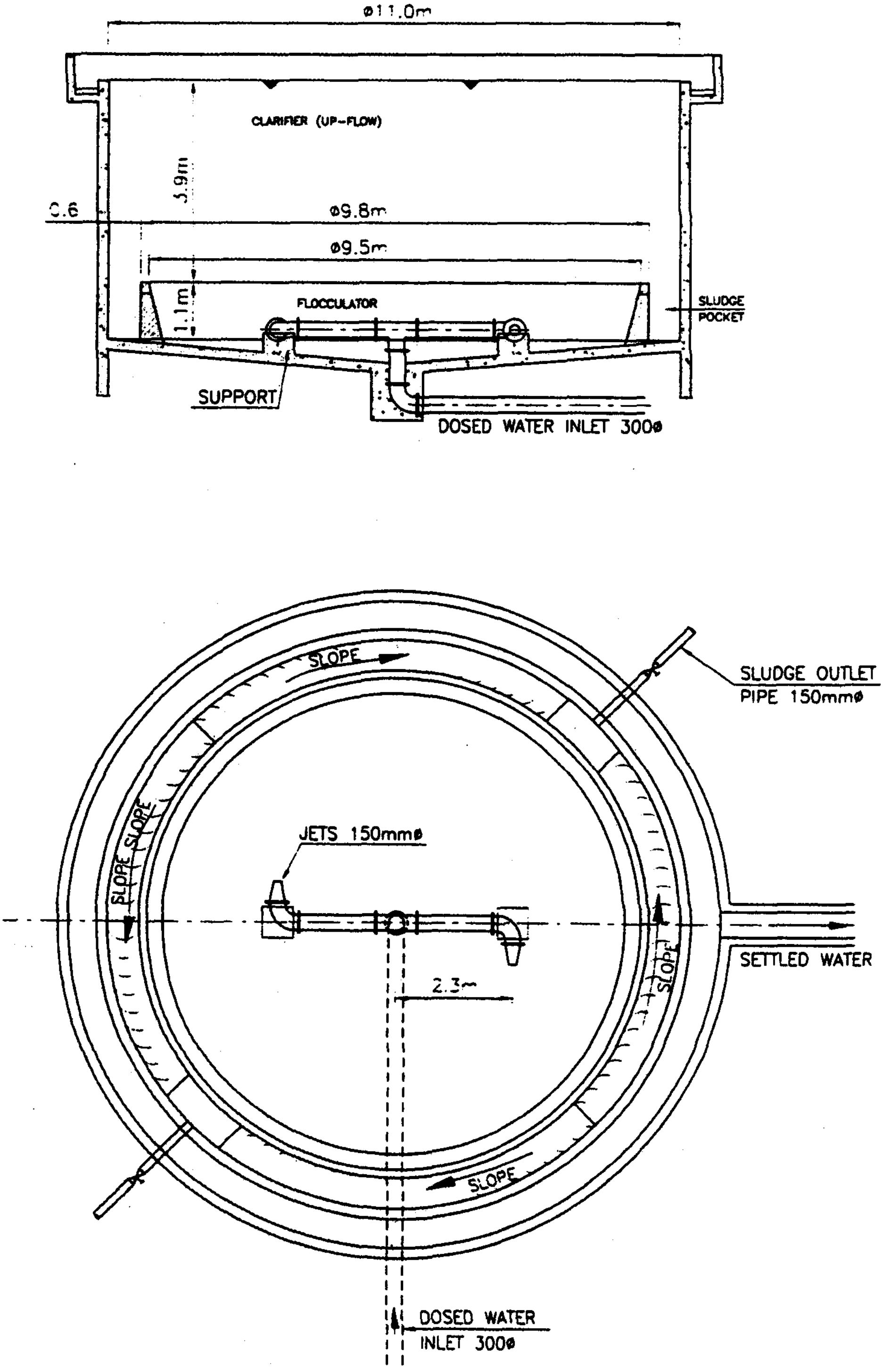

FIG. 2

5 MLD CAP. HIGH RATE FLOCCU-CLARIFIER UNIT

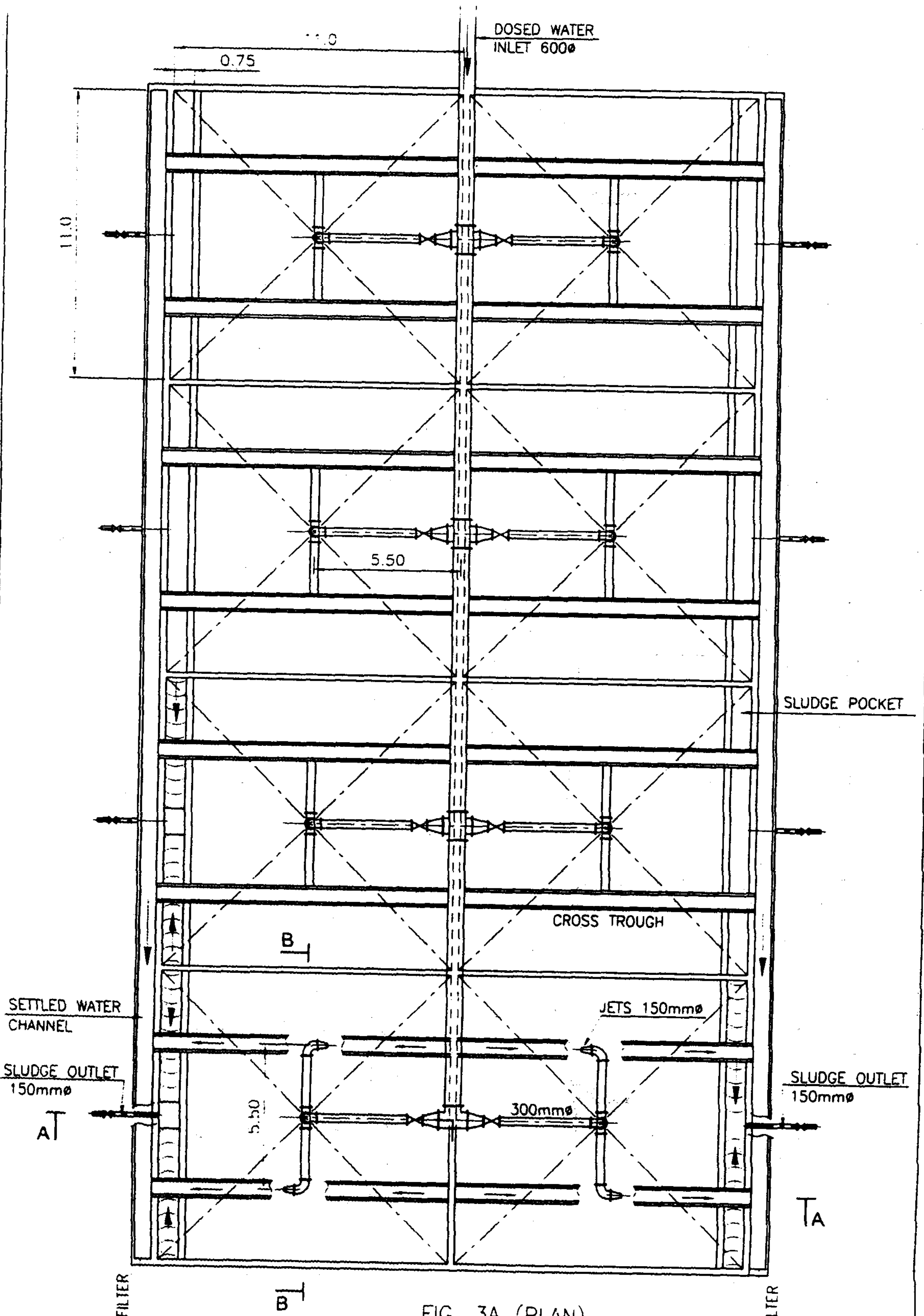

FIG. 3A (PLAN)
50 MLD CAP. HIGH RATE FLOCCU-CLARIFIER UNIT

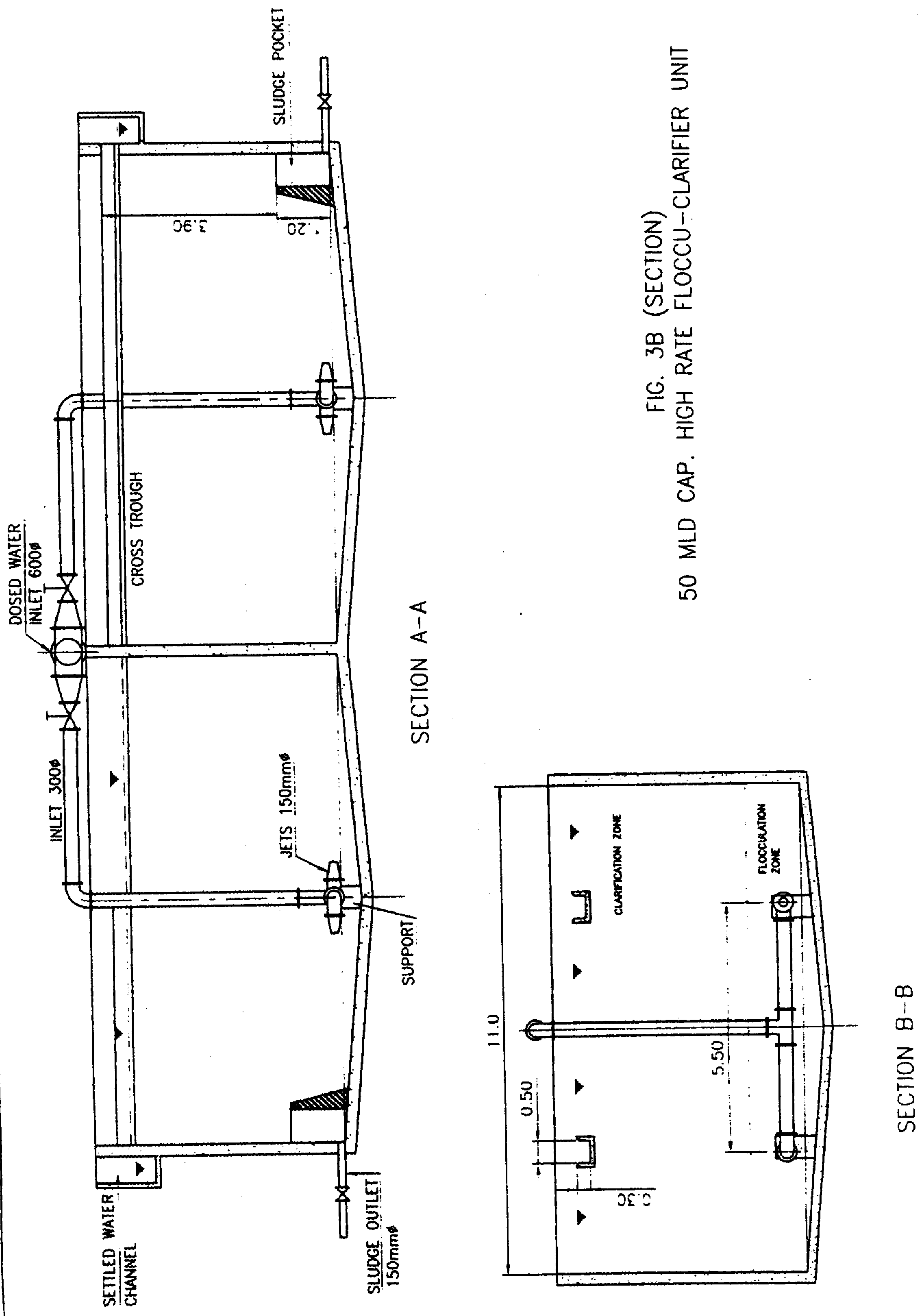

FIG. 3B (SECTION)
50 MLD CAP. HIGH RATE FLOCCU-CLARIFIER UNIT

Types of Units

Following two types of units are suggested:

(1) FC Units Based on Conventional Design Criteria for Horizontal Flow Tanks,

(2) High Rate FC Units (Vertical Flow).

Circular Conventional (Horizontal Flow) & High Rate (Circular and Rectangular) Units (Vertical Flow) are illustrated schematically in Fig.-1, Fig.-2 and Fig.-3, respectively. In both these types of units, flocculation is achieved by jet induced hydrodynamic conditions conducive for flocculation. Use of mechanical equipments, including that for flash mixing, is totally eliminated. The requisite chemical dose must, however, be administered at a suitable point U/s, such as in the inlet channel of Parshall Flume or Cascade Aerator. The flash mixing will take place hydraulically at the bottom of the Jet Flocculator.

(1) FC Units Based on Conventional Design Criteria for Horizontal Flow Tanks

The design of these units is based on normal design criteria for flocculation and clarification as follows:

Flocculation:
Detention Time t = 20 to 40 minutes (Average 30 minutes)
Velocity Gradient G = 10-75 s^(-1)
Product G.t = 10^4 to 10^5

Clarification:
SOR = 1.0 to 1.5 cum/sqm/h
Detention Time = 2.0 to 3.0 hours
Weir Loading < 300 cum/m/d at Qav.

(2) High Rate FC Units

Flocculation:
Detention Time t = 10 to 30 minutes (Average 20 minutes)
Velocity Gradient G = 10-75 s^(-1)
Product G.t = 10^4 to 10^5

Clarification:
SOR = 1.5 to 3.0 cum/sqm/h
Detention Time = 1.5 to 2.0 hours
Weir Loading < 300 cum/m/d at Qav.

Mechanisms at Work

(1) FC Units Based on Conventional Design Criteria for Horizontal Flow Tanks

The mechanisms at work in horizontal flow units are the same as for conventional clariflocculators. The only difference is that the jets replace mechanical paddles.

(2) High Rate FC Units

These units are more akin to the vertical flow sludge blanket clarifiers, though not exactly the same. There is a small difference related to hydrodynamic conditions induced by the jets in the tank. The helicoidal pattern of flow, which is highly pronounced in the flocculation zone at the bottom portion, has been found more conducive to improve flocculation (Bhagwatkar 1994). Theoretically, the flocs attaining settling velocity in excess of the surface overflow rate will accumulate in the sludge pocket (peripheral or on one side) and will undergo concentration prior to its removal to waste drain. Sludge removal is facilitated by provision of sloping floor in sludge pocket. The settled water is collected by the Cross Troughs (CT), which discharge in to the settled water channels leading to filters. The choice of circular or rectangular units will depend on the plant capacity and the site conditions. The different designs are illustrated by typical examples.

ILLUSTRATIVE EXAMPLES

Illustrative Example-1

Typical design calculations for 25 MLD capacity Floccu-Clarifier are enclosed in Appendix-A.

Salient features of the design are stated below:

- The Jet Flocculation System placed at the bottom replaces mechanical paddle flocculation, usually at top, in a conventional Clariflocculator.
- Additional Partition Wall is interposed in the flocculation area to achieve a flow pattern to avoid short-circuiting.
- Water is admitted first at bottom and then moves upward helicoidally and again flows downwards through the annular space created by the partition wall.
- The flocculated water enters the clarification area

at bottom radially, from where it moves to the peripheral launder in exactly the same manner as in the conventional Clariflocculator.

- The sludge removal is arranged from the Sludge Channel in the center of the clarifier. For this purpose, the clarifier floor is sloped in both the directions. Steeper slope of 1 : 4 is used to facilitate collection of sludge to the channel.
- Sludge is removed from the channel to the drainage line by multiple pipes (Usually not more than 4).
- Due to high turbulence at bottom deposition of sludge in the flocculator part is not expected. However, occasionally, any accumulations noticed shall be removed using portable vacuum sludge pump from flocculator part.
- The provision of scraper is optional. However, when it is eliminated, the sludge channel will be located at the periphery, which will permit occasional cleaning of the channel by manual or mechanical sweeping from the peripheral walkway.

Illustrative Example-2

High Rate FC work on the principles of sludge blanket clarifiers. Typical design calculations for 5 MLD capacity High Rate Circular Floccu-Clarifier are enclosed in Appendix-B.

Important features of the design are stated below:

- The jet flocculation system placed at the bottom
- A dwarf wall is interposed coaxially peripherally to the flocculation area
- Water is admitted first at bottom and then moves upward helicoidally to the clarification area above the flocculation area in exactly the same manner as in the sludge blanket clarifiers.
- The sludge removal is arranged from the sludge pocket provided at the periphery.
- Peripheral sludge pocket bottom is provided maximum possible slope to facilitate collection of sludge to the pocket bottom.
- Accumulated sludge is removed periodically from the sludge pocket to the drainage line by multiple pipes (Usually not more than 2).
- Due to high turbulence at bottom deposition of sludge in the flocculator part is not expected. However, occasionally, any accumulations noticed shall be removed using portable vacuum pump sludge from flocculator.
- The provision of scraper is not necessary. When necessary, the pocket bottom may be scrubbed from top, manually.

Illustrative Example-3

This example illustrates the use of new technique for large size plants. Because of the rectangular shape, the space utilization is optimum. Typical design calculations for 50 MLD capacity High Rate Rectangular Floccu-Clarifier are enclosed in Appendix-C.

Important features of the design are stated below:

- The jet flocculation system placed at the bottom
- A dwarf wall is interposed on the outer side of the flocculation area
- The main feeder line is placed at the center and distributes the same nearly uniformly to the branch feeder lines. In this case also, water is admitted first at bottom and then moves upward helicoidally to the clarification area above the flocculation area, in nearly the same manner as in the sludge blanket clarifiers.
- The sludge removal is arranged from the sludge pocket provided on the outer side of flocculator area.
- Sludge pocket bottom is provided with maximum possible slope to facilitate collection of sludge to the pocket bottom.
- Accumulated sludge is removed periodically from the sludge pocket to the drainage line usually by 1 pipe per module.
- Due to high turbulence at bottom, deposition of sludge in the flocculator part is not expected. However, occasionally, any accumulations noticed shall be removed using portable vacuum sludge pump from flocculator.

FIELD VERIFICATION

A circular clarifier unit (7.75 m dia and 4.6 m SWD) in Maharashtra, which was not functioning properly, was modified by incorporating Jet Flocculation System. The detailed performance study is underway. The preliminary observations show quite encouraging performance.

Further Possible Manifestations

With due consideration of the attainable particle settling velocity, further economy in the design presented in Typical Example-3 can be done considering only 4 Modules in place of 8 modules.

SUMMARY AND CONCLUSIONS

1) The paper emphasizes the need to develop water treatment plant designs that minimize the mechanical equipment as much as possible.

2) Floccu-Clarifier (Clariflocculator in established sense) designs based on Jet Flocculation Systems, which eliminate altogether the mechanical components, are presented.

3) The shape of the unit may be circular or rectangular, depending on the size of the plant.

4) High Rate Flat Bottom Sludge Blanket Clarifier designs for small (up to 5 MLD) or large (above 5 MLD) capacity units are suggested.

5) All the designs are illustrated by typical examples covering small and large capacity plants. These examples include:

   (i) 25 MLD Capacity Conventional (Horizontal Flow) Floccu-Clarifier.

   (ii) 5 MLD Capacity Flat Bottom High Rate Circular (Sludge Blanket Type) Floccu-Clarifier.

   (iii) 50 MLD Capacity Flat Bottom High Rate Rectangular (Sludge Blanket Type) Floccu-Clarifier.

6) Preliminary observations on a small circular unit, modified by incorporating jet flocculation system, are quite encouraging. (The detailed investigations on this plant are underway).

7) The new designs based on the concept of Jet Flocculation can be advantageously used for all water treatment plants, small or large, for sustained satisfactory performance.

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APPENDIX-A

Typical Example-1

DESIGN OF 25 MLD CAPACITY CONVENTIONAL FLOCCU-CLARIFIER UNIT

DATA

Average Process Design Flow	**Q**		**25.00**	**MLD**	**Given Value**
			25000.00	cum/d	
			1041.67	cum/h	
			17.36	cum/min	
			0.29	cum/s	
Assumed Overloading Flow	**Q of**	**20%**	***30.00***	***MLD***	
			30000.00	cum/d	
			1250.00	cum/h	
			20.83	cum/min	
			0.35	cum/s	

DOSED WATER INLET

Design Flow			0.35	cum/s	
Inlet Pipe					
Dia.			0.60	m	
Max. Velocity			1.23	m/s	OK
Av. Velocity			1.02	m/s	

DESIGN OF HIGH RATE UNIT

Design Criteria					
Clarifier:					
SOR					
Range	1 to	1.5 m/h			
Average			1.20	m/h	
Flocculator					
DT					
Range	2 to	3.0 h			
Average			2.50	h	
Flocculator					
DT					
Range	20 to	40.0 minutes			
Average			30.00	minutes	
G					
Range	10 to	75 s^(-1)			
Average			30	s^(-1)	
Product G.t					
Range	10^4 to	10^5 s^(-1)			
Central Shaft					
Design Flow			0.35	cum/s	
Inner Dia.			0.90	m	
Max. Velocity			0.55	m/s	
Minimum Structural Thickness			0.25	m	

OD		1.40 m	
SWD (Same as Flocculator)		3.65 m	

Branch Connections

Number of Branches		4.00	
Branch Flows			
Maximum		0.09 cum/s	
Average		0.07 cum/s	
Branch Dia.		0.30 m	
Velocities			
Maximum		1.23 m/s	
Average		1.02 m/s	OK

Flocculator

Dia.			
Inner at Top		14.00 m	
Inner at Bottom		14.00 m	
Average		14.00 m	
Wall Thickness		0.23 m	
Outer (Average)		14.46 m	
30 Minute Volume=		520.83 cum	
Depth		3.39 m	
	Provide	3.65 m	
Provided Gross Volume (Excluding Shaft Volume)		555.97 cum	
Openings at Bottom to Clarifier Section			
Number of Supporting Columns		24.00	
C/c distance of Supporting Columns	**0.25 in Thickness**	1.83 m	
Slot Depth		0.30 m	
Total Area		11.39 sqm	
Average Velocity		0.025 m/s	
Maximum Velocity		0.030 m/s	OK
Partition Wall			
Annular Clearence		0.30 m	
Outer Dia.		13.40 m	
Partition Wall Thickness		0.23 m	
Inner Dia.		12.94 m	
Height of Partition Wall from SWD		3.35 m	
Volume of Partition Wall		31.86 cum	
Openings for Hydraulic Connectivity			
Dia.		50.00 mm	
Number of openings		24.00	
Total Area		0.05 sqm	
Maximum Velocity (Flocculator Full and Clarifier Empty)		0.074 cum/s	(Imaginary Condition)

Net Provided Volume of Flocculator
Gross Volume= 555.97 cum - 31.86 cum Partition Wall Volume 524.11 cum > 520.83 OK

Jet Flocculation System

Inlets

Provide 4 dimetrically opposite jet inlets in flocculator as follows: 4.00

a) 300 Dia. Connecting CIDF Pipe

b) 300 Dia. Standard CIDF 1/4(90 Deg.)Bend (IS 1538:1993)	4.00		
c) 300X200. Standard CIDF Taper (IS 1538: 1993)	4.00	To serve as 200 dia. Jets	
Distance between Jets and Flocculator Inner Wall Face	3.50	m	
Position of Horizontal Plane containing Centre line of the jet system	0.15	m above the Tank Bottom	
Bottom Slope 1 in 4	0.250		
Depth of Flocculator Bottom below SWD at Jet Circle Distance	0.88	m	
Depth of Bottom Floor below Jet Centre	1.03	m	OK
The Jet System shall be firmly secured in its place by anchors from the bottom.		Important	

Calculation for Net Power Requirement

Number of Jets	4.00		
Normal Flow / Jet	0.072	cum/s	
Flocculator Volume	561.59	cum	
DT	32.35	minutes	OK

Net power requirement (P) Watts : P '= (mu) G^2 V

Velocity Gradient (G) (Initial Assumption)	30.00	s^-1	(10-75)
Dynamic Viscosity (at 20 Deg. C) (mu)	0.0010	N.s/m^2	
Net power requirement (P) Watts : P '= (mu) G^2 V	510.48	Watts	
Upflow Velocity in Flocculator at Top	0.00	m/s	
Remaining Kinetic Energy in Water=	0.00	m=Negligible	
Head lost in wall friction in the flocculator during upflow	Negligible		

Net Water Power Dissipation

Adopt Jet Aperture	0.15	m	
Velocity of Jet	4.10	m/s	
Net Head Dissipated	0.85	m	
Water Power	247.37	kgf.m/s	OK
	2426.75	N.m/s=Watts	
Resulting G	65.41	s^-1	OK
G.t=	126950.55	OK (10^4-10^5)	

Outlet

The Jet Flocculator shall deliver the flow to the Clarifier Section through openings at bottom. These openings receive the flocculated water from top through annular well.

Clarifier (Peripheral to Flocculator)		1.00	No.	
Diameter		34.00	m	
SWD	(Same as the Flocculator)	3.65	m	
Net Volume				
Required		2604.17	cum	
Provided		2713.13	cum	
DT available at Average Flow		2.60	h > 2.5	OK
SOR available at Average Flow for Annular Area= 743.32sqm		1.401365 m/h<1.5	at Qav.	OK
Peripheral Channel Outlet				
Maximum Qmax/2		0.17	cum/s	
Width		0.60	m	
SWD		0.50	m	
Max. Velocity		0.58	m/s<0.6	OK
Peripheral Weir				
Weir Length	3.14 X 34.00	106.76	m	
Weir Loading		234.17	cum/m/d <300	OK

Sludge Collection

Sludge Channel			
Width (Annular)		0.60 m	Nominal
Depth		0.50 m	
Dia.		24.30 m	
Bottom Slope	1 to 4	0.25 m	
Fall to Centre Line of Sludge Channel		1.21 m	

Sludge Removal

Notes: a) The Settled Sludge from Clarifier section will get collected in the Annular Sludge Channel.
b) Sludge removal pipes will be provided from the Sludge Channel.
c) Draining of water from flocculator, which may be occasionly necessary, should be done by portable pump.
d) Since the floor slope in clarifier is steeper (1:4) and provided bothways, the overall depth is limited.
e) Sludge removal can take place hydraulically due to steeper slope.
f) However, Half Scraper Bridge moving on peripheral rail may be optionally provided.

Sludge Withdrawal Pipes			
Number of Pipes		4.00	
Dia. (ID)		0.15	m
Sludge Volume/d	1%	250.0000	cum/d
Rate of Discharge/pipe @	1.2 m/s=	0.02	cum/s
Required time to discharge 1 day sludge from all the	4.00 pipes	49.15	minutes
Therefore, operate the each of the sludge valve every	4 hours	8.19	minutes
	Say	9.00	minutes

APPENDIX-B

Typical Example-2

DESIGN OF 5.0 MLD CAPACITY HIGH RATE FLOCCU-CLARIFIER UNIT

DATA

Average Process Design Flow	**Q**		**5.00**	**MLD**	**Given Value**
			5000.00	cum/d	
			208.33	cum/h	
			3.47	cum/min	
			0.06	cum/s	
Assumed Overloading Flow	**Q of**	**20%**	**6.00**	**MLD**	
			6000.00	cum/d	
			250.00	cum/h	
			4.17	cum/min	
			0.07	cum/s	

DOSED WATER INLET

Design Flow	0.07	cum/s	
Inlet Pipe			
Dia.	0.30	m	
Max. Velocity	0.98	m/s	OK
Av. Velocity	0.82	m/s	

DESIGN OF HIGH RATE UNIT

Design Criteria					
Clarifier:					
SOR					
Range	1.5 to	3.0 m/h			
Average			2.50	m/h	
DT					
Range	1.5 to	2.0 h			
Average			1.75	h	
Flocculator					
DT					
Range	10 to 3	0.0 minutes			
Average			20.00	minutes	
G					
Range	10 to	75 s^(-1)			
Average			30	s^(-1)	
Product G.t					
Range	10^4 to	10^5 s^(-1)			

Clarifier (Above the Flocculator)

Number of Units		1.00	No.	
Diameter		11.00	m	
SWD Above the Flocculator		3.90	m	
Total Volume		370.44	cum	
DT available at Average Flow		1.78	h > 1.75	OK
Peripheral Channel Outlet				
Maximum Qmax/2		0.03	cum/s	
Width		0.45	m	
SWD		0.20	m	
Max. Velocity		0.39	m/s<0.6	OK
Peripheral Weir				
Weir Length		34.54	m	
Weir Loading		144.76	cum/m/d <300	OK

Sludge Concentrater

Sludge Pocket				
Width (Annular)		0.60	m Nominal	
Wall Thickness:	At Top	0.15	m	
	At Bottom	0.46	m 2.0 Brick Wall	
Outer Dia.		11.00	m	
Inner Dia.		9.80	m	
Net Plan Area		19.59	sqm	
Average Depth= 0.5	Depth of Flocculator	0.55	m	
Net Volume		10.78	cum	OK

Flocculator

Dia.		
Inner at Top	9.50	m
Inner at Bottom	8.88	m

Average		9.19	m
20 Minute Volume=		69.44	cum
Depth		1.05	m
	Say	1.10	m

Jet Flocculation System

Inlets

Provide 2 dimetrically opposite jet inlets in Flocculator as follows:

a) 300 X 300 X 300 Standard CIDF Tee (IS 1538: 1993)			1.00	Connecting 300 dia. inlet pipe
b) 300 Dia. Connecting CIDF Pipe			2.00	
c) 300 X150 Standard CIDF Taper (IS 1538: 1993)			2.00	To serve as 150 dia. Jets
Distance between Jets and Flocculator Axis			2.30	m
Position of Horizontal Plane containing Centre line of the jet system			0.15	m above the Tank Bottom
Bottom Slope	1 in	12	0.083	
Depth at Centre from SWD			0.46	
Depth from Jet Centre			0.34	OK

The Jet System shall be firmly secured in its place by anchors from the bottom. Important

Calculation for Net Power Requirement

Number of Jets	2.00		
Normal Flow / Jet	0.029	cum/s	
Total Volume of Floccu-Clarifier Module	370.44	cum	
Flocculator Volume	72.93	cum	
DT	21.00	minutes	OK
Net power requirement (P) Watts : P '= (mu) G^2 V			
Velocity Gradient (G) (Initial Assumption)	30.00	s^-1	(10-75)
Dynamic Viscosity (at 20 Deg. C) (mu)	0.0010	N.s/m^2	
Net power requirement (P) Watts : P '= (mu) G^2 V	66.29	Watts	
Upflow Velocity in Flocculator at Top	0.00	m/s	
Remaining Kinetic Energy in Water=	0.00	m=Negligible	
Head lost in wall friction in the flocculator during upflow	Negligible		
Net Water Power Dissipation			
Adopt Jet Aperture	0.15	m	
Velocity of Jet	1.64	m/s	
Net Head Dissipated	0.14	m	
Water Power	7.92	kgf.m/s	OK
	77.66	N.m/s=Watts	
Resulting G	32.47	s^-1	OK
G.t=40918.24		OK (10^4-10^5)	

Outlet

The Jet Flocculator shall deliver the flow to the Clarifier Section above.

Sludge Removal

Notes : a) The Settled Sludge from Clarifier section will get collected in the Annular Sludge Pocket.

b) Sludge removal pipe will be provided from the sludge pocket.

c) Draining of water from flocculator, which may be occasionly necessary, should be done by portable pump.

Sludge Withdrawal Pipes

Number of pipes		2.00		
Dia. (ID)		0.10	m	
Sludge Volume/d	1%	50.0000	cum/d	
Rate of Discharge/pipe @ 1.2 m/s=		0.01	cum/s	
Required time to discharge 1 day sludge (using 2 pipes)		44.23	minutes	
Therefore, operate each of the sludge valve every 8 hours for		14.74	minutes	
Say		15.00	minutes	
Bottom Slope for 1 m Flat Pit and	2.00 SWPs=	0.14		OK

APPENDIX-C

Typical Example-3

DESIGN OF 50.0 MLD CAPACITY HIGH RATE FLOCCU-CLARIFIER UNIT

DATA

Average Process Design Flow	**Q**		**50.00**	**MLD**	**Given Value**
			50000.00	cum/d	
			2083.33	cum/h	
			34.72	cum/min	
			0.58	cum/s	
Assumed Overloading Flow	**Q of**	**20%**	**60.00**	**MLD**	
			60000.00	cum/d	
			2500.00	cum/h	
			41.67	cum/min	
			0.69	cum/s	

DOSED WATER INLET

Design Flow	0.69	cum/s	
Inlet Pipe			
Dia.	0.75	m	
Max. Velocity	1.57	m/s	OK
Av. Velocity	1.31	m/s	

DESIGN OF HIGH RATE UNIT

Design Criteria				
Clarifier:				
SOR				
Range	1.5 to	3.0 m/h		
Average			2.50	m/h
DT				
Range	1.5 to	2.0 h		
Average			1.75	h
Flocculator				
DT				
Range	10 to	40.0 minutes		
Average			30.00	minutes

G				
Range	10 to	75 s^(-1)		
Average			30 s^(-1)	
Product G.t				
Range	10^4 to	10^5 s^(-1)		
Flocculator and Clarifier Combined				
DT				
Range	100 to	150.0 minutes		
Average			135.00 minutes	
			2.25 h	

Clarifier (Above the Flocculator)

Number of Modules		8.00	No.	
Design Flow/Module				
Max. Flow		0.09	cum/s	
Av. Flow		0.07	cum/s	
Inlet Pipe				
Dia.		0.30	m	
Max. Velocity		1.23	m/s	OK
Av. Velocity		1.02	m/s	
Size of Square Unit		11.00	m	
SWD Above the Flocculator		3.90	m	
Total Volume		471.90	cum	
DT available at Average Flow		1.81	h > 1.75	OK
SOR		2.15	m/h	OK
Outlet				
Cross Troughs				
Number		2		
Width		0.50	m	
Max. Depth of Flow				
Max Flow/Cross Trough	3750 cum/d=	0.043	cum/s	
hmax for Free Flow from Eq.	Qmax=1.376*b*h^1.5	0.158	m	
Add Free Board		0.1m		
Provided CT Depth	Say	0.300	m	
Weir Length/Module		44.00	m	
Weir Loading		142.05	cum/m/d <300	OK
Outlet Channel				
Maximum Flow		30000.00	cum/d	
		0.35	cum/s	
Width		0.60	m	
SWD		0.60	m	
Velocity		0.96	m/s<0.6	OK

Sludge Concentrater

Sludge Pocket			
Width on ONE Side	0.75	m	Nominal
Wall Thickness			
At Top	0.15	m	
At Bottom	0.46	m	2.0 Brick Wall

Length		11.00	m	
Net Plan Area		8.25	sqm	
Average Depth=	0.5 Depth of Flocculator	0.60	m	
Net Volume		4.95	cum	OK

Flocculator

Size			
Inner at Top			
Length		11.00	m
Width		10.10	m
Area		111.10	sqm
Inner at Bottom			
Length		11.00	m
Width		9.79	m
Area		107.69	sqm
Average		109.40	sqm
30 Minute Volume =		130.21	cum
Depth		1.19	m
	Say	1.20	m

Jet Flocculation System

Inlets Provide 2 dimetrically opposite jet inlets in Flocculator as follows:

a) 300 X 300 X 300 Standard CIDF Tee (IS 1538: 1993)		1.00	Connecting 300 dia. inlet pipe	
b) 300 Dia. Standard CIDF 1/4 (90 Deg.) Bend (IS 1538: 1993)		2.00		
c) 300 X150 Standard CIDF Taper (IS 1538: 1993)		2.00	To serve as 150 dia. Jets	
d) 300 Dia. CIDF Pipe Distance Piece (IS 1538: 1993)				
Distance between Jets and Flocculator Axis Lengthwise		2.75	m	
Position of Horizontal Plane containing Centre line of the jet system		0.15	m above the Tank Bottom	
Bottom Slope	1 in 12	0.083		
Depth at Centre from SWD		0.46	m	
Depth from Jet Centre		0.38	m	OK
The Jet System shall be firmly secured in its place by anchors from the bottom.			Important	

Calculation for Net Power Requirement

Number of Jets		2.00		
Normal Flow / Jet		0.036	cum/s	
Flocculator Volume		131.27	cum	
DT		30.25	minutes	OK
Net power requirement (P) Watts : P '= (mu) G^2 V				
Velocity Gradient (G)	(Initial Assumption)	30.00	s^-1 (10-75)	
Dynamic Viscosity (at 20 Deg. C) (mu)		0.0010	N.s/m^2	
Net power requirement (P) Watts : P '= (mu) G^2 V		119.33	Watts	
Upflow Velocity in Flocculator at Top		0.01	m/s	
Remaining Kinetic Energy in Water=		0.00	m=Negligible	
Head lost in wall friction in the flocculator during upflow			Negligible	

Net Water Power Dissipation

Adopt Jet Aperture	0.15	m
Velocity of Jet	2.05	m/s

(To be continued on page 43)

(Continued from page 38)

Net Head Dissipated	0.21	m	
Water Power	15.46	kgf.m/s	OK
	151.67	N.m/s=Watts	
Resulting G	33.82	s^-1	OK
G.t=	61378.27	OK (10^4-10^5)	

Outlet

The Jet Flocculator shall deliver the flow to the Clarifier Section above.

Sludge Removal

Notes:

a) The Settled Sludge from Clarifier Section will get collected in the Sludge Pocket on one side.
b) Sludge removal pipe will be provided from the sludge pocket.
c) Draining of water from flocculator, which may be occasionly necessary, should be done by portable pump.

Sludge Withdrawal Pipes

Number of Pipes = Number of Modules =			8.00	Numbers
Dia. (ID)			0.15	m
Sludge Volume/Module/d	1%		62.50	cum/d
Rate of Discharge/pipe @	1.2 m/s =		0.02	cum/s
Required time to discharge 1 day sludge			49.15	minutes
Therefore, operate each of the sludge valve every		4 hours for	8.19	minutes
		Say	9.00	minutes