جمهورية العراق
وزارة التعليم العالي والبحث العلمي
الجامعة التكنولوجية / قسم هندسة البناء والانشاءات
(فرع الصحية والبيئية)

Design of Bar Racks (Bar Screens)

اعداد الطالبة: فرح يقدم زكي
المرحلـــة : الرابعـــة
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الاهــداء

الى الرحمة المهداة...

الى من تشتاق لرؤيته العيون وتهيم به الارواح ....

الى معلمنا الاول... الى الأسوة الحسنة.....

الى الروح الطاهرة التي تزكي ارواحنا....

الى من اسعد الله به الانسان ...وشرف الزمان وعطر المكان ...

الى صاحب الرسالة المحمدية...

((اليك ياشفيعنا يا رسول الله))

الى اغلى الغوالي ،الذي استمد منه زاد ممشواري .....

الى الجبين العالي ،ذو العطاء المتفاني ...

الى النور الذي ينير طريقي وسط ظلمات الحياة ....

الى الذي علمني معنى التواضع والعطاء ،والتسامح والوفاء.....

الى قدوتي في الحياة.....

((ابـــــــــــــــي))

حفظه الله واطال في عمره

الى اليد الحنونة التي رعتني وربتني ،الى العيون التي سهرت على نجاحي ....

الى نبع الحنان الذي لاينضب ،الى القلب الواسع الطيب ...

الى خير صديق و رفيق ينير لي عتمة الطريق .....

الى من تتداعىالكلمات امامها ،اطال الله في عمرها.....

((امـــــــــــــــي))

الى الاغصان الخضراء التي كانت لي سندا ....

الى نسيم الحياة الذي لا استغني عنه ابدا.....

الى الذين منحوني حبهم و اخلاصهم ....

((اخـــــي و اختـــــي))

الى الغد المشرق في عيوني...

الى بسمة الحنان و عنوان وجودي...

الى زهرة قلبي ونور عيني ...

((زوجـــي))

شكر وتقدير

لايسعني الا ان اتقدم بوافر شكري وتقديري

الى اساتذتي الافاضل

واخص بالذكر منهم الاستاذ ....

الدكتور

ثائـــر شـــريـــف

لماقدمه لي من ارشادات وتوجيهات قيمة ساهمت في رفد البحث ....

والى كل من مد لي يد العون والمساعدة

List of contents

Chapter Four

Design Criteria of Bar Screens

Chapter 5:

Design of Bar Racks

Figures: pages

Tables: pages

CHAPTER ONE

Chapter One

1-1- Introduction:

The first unit found at treatment plants is used to remove trash and coarse solids (wood, cloth, paper, plastics, garbage, etc.). Screening devices may consist of parallel bars, gratings, wire mesh, or perforated slots. The parallel bar or rod configuration is called a trash rack or bar screen and will have openings (space between bars) of $^5/_8$" or more. The 1990 edition of "Recommended Standards for Wastewater Facilities of the Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers" (commonly referred to as "Ten States' Standards") lists these as coarse screens. This publication recommends openings for manually cleaned bar racks be from 1" to $1^3/_4$" and placed on a slope of 30 to 45 degrees from the horizontal. It also recommends approach velocities be at least 1.25 fps to prevent settling and not more than 3.0 fps to prevent forcing material through the openings.

The term "screen" is used for screening devices consisting of perforated plates, wedge wire elements, and wire cloth and the openings will be less than $^5/_8$". "Ten States' Standards" refers to screens with openings of approximately 1/16 inch as fine screens that can be used in lieu of primary sedimentation. Commonly used screens include the hydro sieve or inclined fixed screen and the rotary drum screen. A primary concern of screening devices is the potential head loss through them, which increases with the degree of clogging. If they are not self cleaning; it is imperative that the operator clean them several times each day to prevent a damming effect that results in grit being deposited upstream from the unit. Where fine screens are used, consideration should be given to the prior removal of floatable oils and greases, which can clog the openings.

1-2- Objectives:

1- Determination of peak design wet weather flow, max. design dry weather flow and average design dry weather flow.
2- Calculation of flow conditions in the incoming conduit.
3- Design of rack (screen) chamber.
4- Calculation of bottom slope of the channel below the rack.
5- Hydraulic profile through the bar rack.
6- Calculation of the quantity of screenings.
7- Disposal of screening.
8- Provide a design details.

CHAPTER TWO

Chapter Two

2-1- Introduction:

In 1994, the U.S. Environmental Protection Agency (EPA) recognized the importance of controlling solid and floatable materials under the "nine minimum controls" described in the Combined Sewer Overflow (CSO) Control Policy. CSOs can contain high levels of floatable materials, suspended solids, biochemical oxygen demand (BOD), oils and grease, toxic pollutants, and pathogenic microorganisms. Floatables are often the most noticeable and problematic CSO pollutant. They create aesthetic problems and boating hazards, threaten wildlife, foul recreational areas, and cause beach closures. There are numerous methods available for floatables control, including baffles, catch basin modifications, netting systems, containment booms, skimming processes, and screening and trash rack devices. These technologies are summarized in EPA's CSO Technology Fact Sheet entitled "Floatables Control" (EPA 832-F-99-008). This fact sheet focuses on screens and trash racks for CSO floatables control.

Screens are considered an effective and economically efficient method of removing solids and floatables from CSOs. CSO screens are typically constructed of steel parallel bars or wires, wire mesh (wedgewire), grating, or perforated plate; some screens, however, are constructed of milled bronze or copper plates. In general, the openings are circular or rectangular slots, varying in size from 0.25 to 15.24 centimeter (0.1 to 6 inch) spacings. The amount and size of the solids and floatables removed is dependent on the type of screen and the size of the screen openings. Solids are removed from the flow by two basic treatment mechanisms:

- Direct straining of all particles larger than the screen openings.
- Filtering of smaller particles by straining flow through the mat of

solids already deposited on the screen.

Generally there are two types of bar screens- coarse and fine. Both are used at CSO control facilities, with each different type providing a different level of removal efficiency. While there is no industry standard for classifying screens based on aperture size coarse bar screens generally have 0.04 to 0.08 meter (1.5 to 3.0 inch) clear spacing between bars and fine screens generally have rounded or slotted openings of 0.3 to 1.3 centimeters (0.1 to 0.5 inch) clear space.

2-2-Coarse Screens

Course screens are constructed of parallel vertical bars and are often referred to as bar racks or bar screens. In CSO control and treatment facilities, coarse screens are usually the first unit of equipment in the system. These screens are usually set at 0 to 30 degrees from vertical and are cleaned by an electrically or hydraulically driven rake mechanism that removes the material entrained on the screen on a continuous or periodic basis. There are three types of bar screens used at CSO control facilities: trash racks; manually cleaned screens; and mechanically cleaned screens.

- Trash racks

Trash racks (also known as trash grates) are intended to remove only very large objects from the flow stream. Trash racks are generally provided at the intersection of the combined sewer and the .sanitary interceptor to prevent major blockages in the interceptor or to protect pumping equipment. Since both dry and wet weather flows pass through this type of screening device, daily cleaning is usually required. Trash racks typically have 0.04 to 0.08 meter (1.5 to 3.0 inch) clear spacing between bars. Figure 1 is a diagram of a typical trash rack.

-Manually cleaned bar screens

Manually cleaned bar screens have a 2.54 to 5.08 centimeter (1.0 to 2.0 inches) clear spacing between bars. The bars are set 30 to 45 degrees from the vertical and the screenings are manually raked onto a perforated plate for drainage prior to disposal.

-Mechanically cleaned bar screens

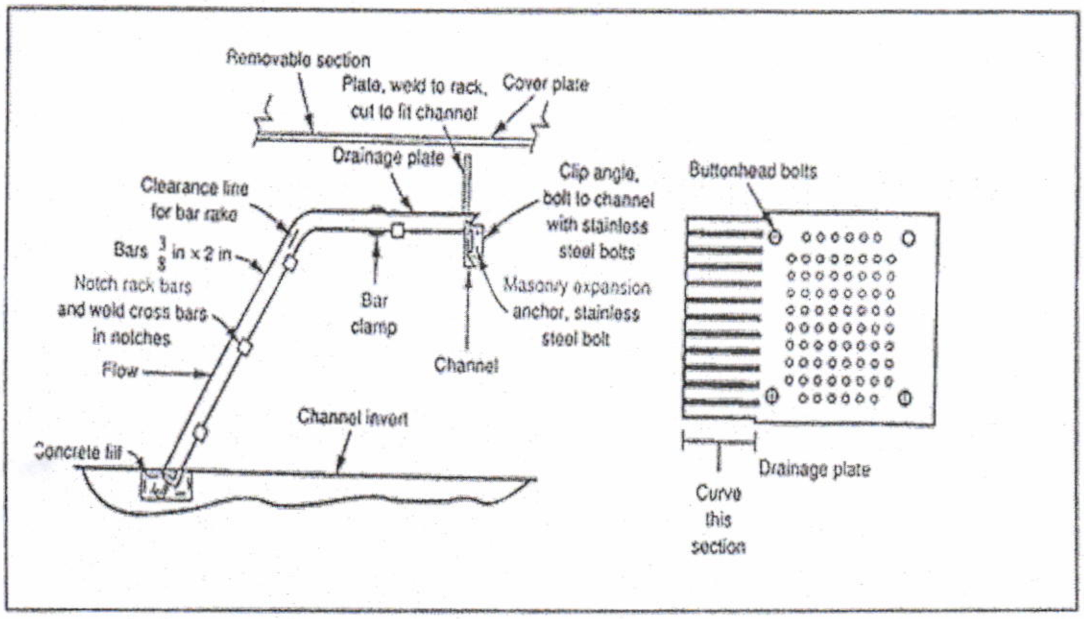
Mechanically cleaned bar screens have a 0.64 to 2.54 centimeter (0.25 to 1.0 inch) clear spacing between bars. The bars are set 0 to 30 degrees from the vertical. Electrically driven rake mechanisms will either continuously or periodically remove material entrained on the bar screen itself. The three common types of mechanically cleaned screens are: (1) chain driven, (2) climber type rake, and (3) catenary.

Chain driven mechanical raking systems consist of a series of bar rakes connected to chains on each side of the bar rack. During the cleaning cycle, the rakes travel in a continuous circuit from the bottom to the top of the bar rack, removing materials retained on the bars and discharging them at the top of the rack. A disadvantage of chain-driven systems is that the lower bearings and sprockets are submerged in the flow and are susceptible to blockage and damage from grit and other materials. Accelerated chain wear and corrosion can also be a problem.

Climber-type systems employ a single rake mechanism mounted on a gear driven rack and pinion system. The gear drive turns cogwheels that move along a pin rack mounted on each side of the bar rack. During the cleaning cycle, the rake mechanism travels up and down the bar rack to remove

materials retained on the bars. Screenings are typically discharged from the bars at the top of the rack. This type of bar screen has no submerged bearings or sprockets and is, therefore, less susceptible to blockages, damage and corrosion than chain driven units.

Catenary systems also employ chain-driven rake mechanisms, but all sprockets, bearings, and shafts are located above the flow level in the screenings



Source: Metcalf and Eddy, 1991.

FIGURE (2-1) DIAGRAM OF TRASH RACK USED FOR TREATMENT OF CSOs

Channel . This in turn reduces the potential for damage and corrosion and facilitates routine maintenance. During the cleaning cycle, the rakes travel in a continuous circuit from the bottom to the top of the bar rack to remove materials retained on the bars. Screenings are typically discharged from the bars at the top of the rack. The cleaning rake is held against the bars by the weight of its chains, allowing the rake to be pulled over large objects that are lodged in the bars and that might otherwise jam the rake mechanism.

2-3: Fine Screens

Fine screens at CSO facilities typically follow coarse bar screening equipment and provide the next level of physical treatment in removing the smaller solid particles from the waste stream. Both fixed (static) and rotary screens have been used in CSO treatment facilities.

Fixed fine screens are typically provided with horizontal or rounded slotted openings of 0.02 to 1.27 centimeters (0.010 to 0.5 inches). The screens are usually constructed of stainless steel in a concave configuration, at a slope of approximately 30 degrees. Flow is discharged across the top of the screen. The flow then passes through the slotted openings and solids are retained on the screen surface. Solids are discharged from the screen surface by gravity and by washing onto a conveyer belt or other collecting system.

Rotary fine screens include externally and internally fed screens. Externally fed screens allow wastewater to flow over the top of the drum mechanism and through the screens while collecting solids on the screen surface. As the screen rotates, a system of cleaning brushes or sprayed water removes debris from the drum. Internally fed systems discharge wastewater in the center of the drum, allowing water to pass through the screen into a discharge channel, while solids are removed from the screen surface by cleaning brushes or a water spray. Screened material is usually washed from the screen with a high pressure spray into a discharge trough. Screen diameters can range from 0.5 to 2 meters (1.6 to 6.6 feet), while the lengths can vary from 2 to 6 meters (6.6 to 19.7 feet). There are three modes of operation which include:

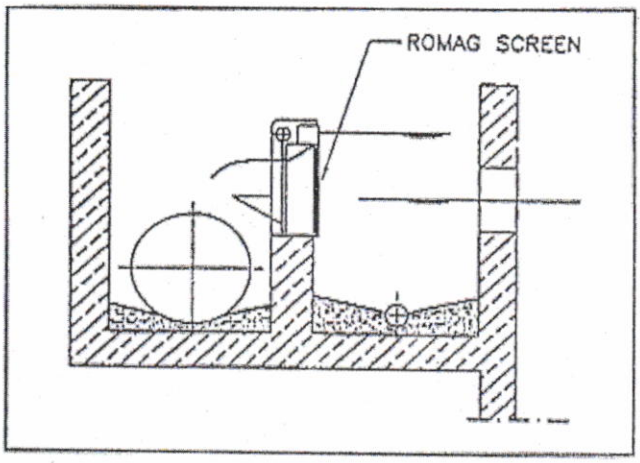
- Low Flow- no drum movement.
- Intermediate Flow- drum moves a short distance and stops with brush

coming on as head loss rises.

- High Flows- continuous operation where the drum rotates at 1 rpm and brush at 10 rpm.

In response to the need for solids and floatables control during storm events, proprietary screen products, such as the ROMAG™ screen (Figure 2-2), have been designed for wet weather applications. The ROMAG™ screen partitions the flow, sending screened flow to the CSO discharge point, while keeping solids and floatables in the flow directed towards the sanitary sewer.

The ROMAG™ screen works as follows: excess flow enters the screening chamber, flows over a spill weir and proceeds through the screen into a channel which discharges flow to a receiving water body. Floatables trapped by the screen move laterally along the face of the screen via combs/separators to the transverse end section of the pipe where they can be directed to the sanitary sewer line for ultimate removal at the wastewater treatment plant. Screen blinding is prevented by a hydraulically-driven rake assembly.



Source: Pisano, 1995.

FIGURE(2-2) ROMAG™ "COMBING"
MECHANICAL SCREEN (VERTICAL) FOR CSO
FLOATABLES CONTROL

both sides to facilitate inspections and maintenance. The screen consists of horizontal bars with 4 mm (0.16 inches) openings that are mounted on a weir in the collection system. Screens range from 2 to 9 meters (6.6-29.5 feet) in length and 330-1200 mm (13- 47.2 inches) in height. Units can be stacked to create a customized mesh opening for a specified design flow at a particular location. The nominal velocity through the bar openings is approximately 1.5 meters per second (4.9 feet per second).

The hydraulically driven mechanical combs used to clean the screen move laterally along the front face of the screen when activated by a level control, which detects rising water. As the screen surface is cleaned, captured material is transported forward to the end section for storage and subsequent removal. The hydraulic combing unit is located outside the screen and consists of an oil tank, pump and control valves.

The ROMAG™ screen may be designed for a variety of flow scenarios. Water may pass through the screen horizontally (RSW type), as shown in Figure (2-2); over the top of the screen (RSO type) or up from under the

screen (RSU) type. This unit has proven useful in remote settings and is capable of handling flows from 300-6100 L/sec (6-140 MOD).

2-4: APPLICABILITY

While screening is widely used to control solids and floatables at the headworks of wastewater treatment plants, screening for solids at remote locations, such as at CSO or storm water overflow points, is less common. However, some types of screens are effective for remote solids and floatables control due to their large aperture size and self-cleaning ability. As a result, mechanically-cleaned bar screens have proven to be a relatively simple and inexpensive means of removing floatables and visible solids. They are typically the screen of choice in many CSO treatment facilities, and are widely used or implemented at a large number of CSO facilities across the country and abroad.

There has been less success in removing fine solids from storm water and CSO overflows. However, proprietary methods, such as the Romag™ screen, have addressed this issue. More than 250 Romag™ screens have been installed in Europe since 1990. Recently, several Romag™ screens have been installed in the U.S. The first was installed in Rahway, NJ, in 1997.

In addition, Deerfield, Illinois has had success utilizing rotating fine screens at their overflow facilities. Their fine screens have 1.02 millimeter (0.04 inch) openings that remove all large solids and floatables. The screened wastewater is discharged inside the screen and conveyed to a chlorine contact tank for disinfection prior to discharge to the receiving stream. The screenings are conveyed by internal conveyors to a discharge chute for storage and eventual return to the POTW at the end of the overflow event. The entire operation is automatic (West et al., 1990).

2-5: ADVANTAGES AND DISADVANTAGES

Since screening is a physical treatment process, it will remove only those objects that are larger than the screen openings. Screening systems are very effective in removing floatable and visible solids, but do not remove a significant amount of suspended solids. In cases where water quality evaluations indicate the need for removal of suspended solids or oxygen demanding materials, additional treatment processes downstream from the screening units would be required.

Because screens at CSO control facilities remove debris, rags, and other floatables that would otherwise be discharged into a receiving stream, they are vital in preserving water quality and aesthetics. Unscreened material in CSOs can become a nuisance if the floatables, and other solids end up in receiving waters. They can create navigational hazards, attract nuisance vectors, and retain bacteria and other pollutants.

Properly screened and removed materials in CSSs prevent materials from settling out in the system, thus preventing potential back ups and possible overflows elsewhere. The screenings and debris that are removed from the screens are typically not hazardous and can be disposed of in a licensed landfill or incinerated. Negative environmental impacts can occur from improper disposal of screened materials, such as by stockpiling in areas adjacent to receiving waters or in areas where they may be seen by the public.

2-6: DESIGN CRITERIA

Hydraulic losses through bar screens are a function of approach velocity and the velocity through the bars. The head loss through a clean bar screen can be estimated using the following equation:

$$h_L = (1/0.7) * ((V^2 - v^2)/2g)$$

where :

h_L = head loss, ft (m)

0.7 = an empirical discharge coefficient to account to turbulence and eddy losses.

V = velocity of flow through the openings of the bar racks, ft/s (m/s)

v = approach velocity in upstream channel, ft/s (m/s)

g = acceleration due to gravity, ft/s^2 (m/s^2)

Head loss increases as the bar screen becomes clogged, or blinded. For coarse screens, the approach velocity should be at least 0.38 meters per second (1.25 feet per second) to minimize deposition, while the velocity through the bars should be less than 0.91 meters per second (3 feet per second) to prevent entrained solids from being forced through the bars. Instrumentation provided with mechanically-cleaned screens is configured to send a signal to the cleaning mechanism so the head loss across the screen is limited to 6 inches.

The following general factors should be considered in the design and operation of coarse and fine screens:

- Grit classifiers are effective in separating, washing, and dewatering grit, sand, finds, and silt from an effluent flow normally downstream form the screens.

- Coarse screens with moving parts out of the flow stream are preferable to coarse screens with submerged parts.

- Fine screens using steel wire mesh or perforated panels are very prone to clogging from fibrous materials and are not easily cleaned. Plastic mesh panels have proven to be effective, are resistant to clogging and are easily cleaned with water sprays.

Pumping or conveying large amounts of large and small solids typically removed by screening systems has proven to be very difficult and a major maintenance problem. Screw conveyors and compactor type screws have been shown to be effective in handling solids, especially those removed by fine screens. Design parameters for different types of screens are given on Tables(2- 1)and(2- 2).

Additional design issues to consider include:

- Grit will tend to accumulate upstream and downstream of screens. Provisions must be made for easy access to such areas and alternative methods of grit removal, including vacuum systems, high pressure water cannons or spray systems.
- Backwater from a storage/sedimentation tank effluent weir can create quiescent settling conditions in the bar screen channel. Therefore, a means of flushing or backwashing the screenings channel should be provided.
- A redundant or back-up bar screen should be provided so that peak flow to the facility can be maintained with one unit out of service. Providing stop grooves or slide

TABLE(2-1) DESIGN PARAMETERS FOR STATIC SCREENS

Hydraulic loading, gal/min/ft of width	100-180
Incline of screens, degrees from vertical*	35
Slot space, μm	250-1600
automatic controls one	None

* Bauer Hydrasieves ™have 3-stage slopes on each screen: 25°, 35°, 45°.

Note: gal/min/ft X 0.207 = l/m/s

- gates in the channel allows the user to isolate the screen from the flow for maintenance.
- Guards, railings, and gratings should be provided in the area around the screening equipment to ensure operator safety. Electrical fittings and equipment associated with the screening equipment must conform to the exposure rating for the space in which the equipment is located.

2-7: Removal Efficiency

Removal efficiency is a function of bar screen; spacing and floatable solids characteristics, Removal efficiency increases as the size and concentration of the solids increases and the spacing dimension decreases. Screenings typically containing 10-20 percent dry solids will typically ; a bulk density ranging from 640 to 1100 grams per cubic meter (40 to 70 pounds per c foot). Typical floatable removal rates for se screens range from 3.5 to 84 liters per 1000 c meters (0.469 to 11.2 cubic feet per MG).

The quantity of screenings can vary greatly and, in general, depends on the following factors:

- Configuration of the drainage system.
- Time of year.
- Interval between storms.
- Intensity of the storm.

TABLE (2-2) DESIGN PARAMETERS FOR DRUM SCREENS AND ROTARY SCREEN

Parameter	Drum/Band screen	Rotary Screen
Screen spacing, μm	100-420	74-167
Screen material	stainless steel or plastic	105 recommended
Drum speed, r/min		stainless steel or

		plastic
Speed range	2-7	30-65
Recommended speed	5	55
Peripheral speed, ft/s		14-16
Submergence of drum,%	60-70	
Flux density, gal/ft^2/min	20-50	70-150
Of submergence		
Hydraulic efficiency,		75-90
% of inflow		
Head loss, in.	6-24	
Backwash		
Volume, % of inflow	0.5-3	0.02-2.5
Pressure, Ib/in^2	30-50	50

Note: gal/ ft^2/ min x 2.44 = m^3/h/m^2

in. X2.54 = cm

ft X 0.305 = cm; Ib/in.^{2}X 0.0703 = kg/cm^2

- Velocity of the flow through the screens.
- Screen aperture.

Studies have found average CSO screenings loads varying from approximately 3.7xlO-^{9}- 8.23x10-^{8} cubic meters per liter (0.5 to 11 cubic feet per million gallons), with peaking factors based on hourly flows ranging from 2:1 to greater than 20:1.

Field studies performed in Canada and Europe have revealed the following floatable removal efficiencies:

- Samplings taken at different CSO outfalls in Montreal, Canada showed that up to 80 percent of floatable material can be retained by properly designed bar screens with 6.35 millimeters (0.25 inch) bar spacing.

- A year-long study was conducted in Germany to determine the efficiency of an externally fed rotary screen in controlling downstream floatable pollution. The screen, which was activated by high flows, received 42 percent of the CSO discharge, with no visible solids reported after frequent inspections of river banks.

- A pilot study in Great Britain tested a 4 mm ROMAG™ bar spaced "weir mount" storm overflow screen. The average solids loading before the screen was 2369 grams per minute, while the solids concentration after the screen was 3.5 grams per minute, exhibiting a 98.5 percent deflection rate. In a similar study, on 11 different occasions during a 12 week period, average mass reduction of floatables and solids material greater than 6 millimeters (0.24 inches) was 98.5 percent.

2-8: OPERATION AND MAINTENANCE

Instrumentation and control of screens typically includes some combination of the following:

- Manual start/stop.
- Automatic start/stop on timer.
- Automatic start/stop on differential head.

Activation of mechanically cleaned screens is triggered by remote sensing of flow into the screenings channel, or the water level in the screening channel.

As screens are subject to blinding from grease and the "first flush" in a CSO event, the screen should be kept clean to minimize headless. Due to the intermittent nature of CSOs it is important for the screening units spray system to be working properly to prevent solids from drying and sticking to the screens, thus increasing headlosses. Fine screens can be cleaned with high pressure water, steam, or cleaning agents to maintain performance. Screening systems should be regularly inspected to ensure that chains and roller mechanisms are lubricated and functioning. The trunnions associated with fine screens are the least reliable component due to the abusive forces they receive. The manufacturer's operation and maintenance manual should be consulted for the maintenance requirements and schedules.

CHAPTER THREE

Chapter Three

DESIGN POPULATION & Volume of wastewater

3-1: General

The required treatment is determined by the influent characteristics, the effluent requirements, and the treatment processes that produce an acceptable effluent. Influent characteristics are determined by laboratory testing of samples from the waste stream or from a similar waste stream, or are predicted on the basis of standard waste streams. Effluent quality requirements are set by Federal, interstate, State, and local regulatory agencies. Treatment processes are selected according to influent-effluent constraints and technical and economic considerations.

3-2 : Design population

Treatment capacity is based on the design population, which is the projected population obtained by analysis. The design population is determined by adding the total resident and 1/3 the non-resident populations and multiplying by the appropriate capacity factor which allows for variations in the using population. The resident population is determined by adding the following:

Table 3-1. Capacity factors.

Effective Population	Capacity Factor
under 5,000	1.50
5,000	1.50
10,000	1,25
20,000	1.15
30,000	1.10
40,000	1.05
50,000	1.00

3-3: Estimating future service demand.

The nature of the activities of the personnel at military installation are a very important factor in determining per capita waste loads because different activities have different water uses. Table 3-2 illustrates this fact in terms of gallons per capita per day (gpcd); table 3-3 shows how waste loadings vary between resident and nonresident personnel. The values shown in table 3-3, for that portion of the contributing population served by garbage grinders, will be increased by 30 percent for biochemical oxygen demand values, 100 percent for suspended solids, and 40 percent for oil and grease. Contributing compatible industrial or commercial flows must be evaluated for waste loading on a case-by-case basis.

Table 3-2. Per capita sewage flows.

Type of Unit	For Resident Personnel (gpcd)	
	Permanent	Field Training
Hospital units	300-600	100
All other unite	100	35

NOTE: Add 30 gallons per 8—hour shift per capita for non-resident and civilian personnel.

Table 3-3. Sewage characteristics.

Item	Resident Personnel Ib/capita for 24 hrs	Non-resident Personnel Ib/capita for 8-hr shift
Suspended Solids	0.20	0.10
Biochemical Oxygen Demand	0.20	0.10
Oil & Grease	0.09	0.05

3-4: Volume of wastewater.

a. Variations in wastewater flow. The rates of sewage flow at military installations vary widely throughout the day. The design of process elements in a sewage treatment plant is based on the average daily flow. Transmission elements, such as conduits, siphons and distributor mechanisms, will be designed on the basis of an expected peak flow rate of three times the average rate. Clarifiers will be designed for a peak hourly flow rate (i.e., 1.75 times the average daily rate). Consideration of the minimum rate of flow is necessary in the design of certain elements, such as grit chambers, measuring devices and dosing equipment; for this purpose, 40 percent of the average flow rate will be used.

b. Average daily wastewater flow. The average daily wastewater flow to be used in the design of new treatment plants will be computed by multiplying the design population by the per capita rates of flow determined from table 3-2, and then adjusting for such factors as industrial wastewater flow, storm water inflow and infiltration. Where shift personnel are engaged, the flow will be computed for the shift when most of the people are working. A useful check on sewage volumes would be to compare water consumption to the sewage estimate (neglecting infiltration, which will be considered subsequently). About 60 to 80 percent of the consumed water will reappear as sewage, the other 20-40 percent being lost to irrigation, fire-fighting, wash-down, and points of use not connected to the sewer.

(l) Good practice requires exclusion of storm water from the sanitary sewer system to the maximum practical extent. Infiltration must also be kept to a minimum. Both must be carefully analyzed and the most realistic practical quantity that can be used in design must be assigned

to these flows, Leakage of storm water into sewer lines often occurs through manhole covers or collars, but this usually is no more than 20 to 70 gallons per minute if manholes have been constructed and maintained properly. However; leakage into the sewer mains and laterals through pipe joints and older brick manholes with increase in groundwater levels can result in large infiltration. The amount of water that actually percolates into the groundwater table may be negligible if an area is occupied by properly guttered buildings and paved areas, or if the subsoil is rich in impervious clay. In other sandy areas, up to 30 percent of rainfall may quickly percolate and then lift groundwater levels. Infiltration rates have been measured in submerged sewer pipe. Relatively new pipe with tight joints still displayed infiltrations at around 1,000 gallons per day per mile, while older pipes leaked to over 40,000 gallons per day per mile. Sewers built first usually followed the contour of water courses and are often submerged while more recent sewers are not only tighter, but are usually built at higher elevations as the system has been expanded. In designing new treatment facilities, allow for infiltration as given in TM 5-814-1/AFM 88-11, volume 1, except as modified by this design manual. Utilize existing flow records, sewer flow surveys, and examine the correlation between recorded flows and rainfall data to improve the infiltration estimate. The economic feasibility of improving the collection system to reduce the rate of infiltration should be considered.

(2) Another method for calculating the infiltration component of total flow is to multiply the miles of a given pipe size and condition by the diameter in inches and to sum the inch-miles. The sums of inch-miles of pipe estimated according to conditions are then multiplied by factors between 250 and 500 to obtain gallon/day. If infiltration is known to be negligible at manholes, then an infiltration allowance may be calculated based upon

area served and figure 3-1. Curve A should be used for worst conditions when pipes are old and joints are composed of jute or cement. Curve B applies to old pipes with hot or cold asphaltic joints or for new pipes known to have poor joints. Curve C is used for new sewers where groundwater does not cover inverts and when joints and manholes are modern and quite tight. Of course, field tests may be conducted to more closely estimate infiltration.

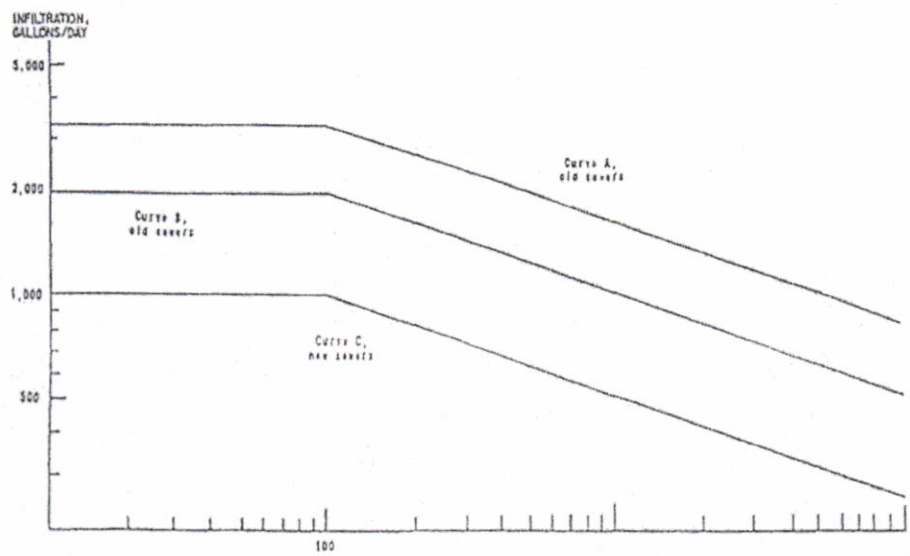


Figure 3-1 Infiltration allowances

(3) Average wastewater flow is usually expressed in million gallons per day, but will be calculated in the appropriate units for design of the unit process under consideration.

c. Contributing populations. In calculating contributing populations, use 3.6 persons per family residen-tial unit. In hospitals, count the number of beds, plus the number of hospital staff eating three meals at the hospital, plus the number of shift employees having one meal there. This total is the number of resident personnel to be used in the design calculations. Individuals will be counted only once, either at home or at work. The capacity factor still applies in calculating design populations.

d. **Industrial flow.** Industrial wastewater flows will be minimal at most

military installations. When industrial flows are present, however, actual measurement is the best way to ascertain flow rates. Modes of occurrence (continuous or intermittent) and period of discharge must also be known.

Typical industrial discharges include wastewaters from the following:

- wastewater treatment plant itself;
- maintenance facilities;
- vehicle wash areas;
- weapons cleaning buildings;
- boiler blowdowns;
- swimming pool backwash water;
- water treatment plant backwash;
- cooling tower blowdown;
- fire fighting facility;
- photographic laboratory;
- medical or dental laboratories.

e. Stormwater flow. Including stormwater flows is important in treatment plant design either when combined sewer systems are served or when significant inflow enters the sewer system. Combined sewer systems will not be permitted in new military installations. Separate sewers are required and only sanitary flows are to be routed through treatment plants. For existing plants that are served by combined sewer systems, capacities will be determined by peak wet-weather flow determined from plant flow records. In the absence of adequate records, hydraulic capacities of four times the dry-weather flow will be used in the design. (Reference to existing systems is applicable to Army facilities only.)

3-5: Population equivalents.

Suspended solids and organic loading can be interpreted as population equivalents when population data constitute the main basis of design. Typical population equivalents applicable to military facilities were given in table 3-3. These equivalent values can also be used to convert non-domestic waste loads into population design values. The effects of garbage grinding will be incorporated into population-equivalent values when applicable. The waste stream to be treated at existing military installations should, when feasible, be characterized; this actual data should be used in the design.

3-6:Capacity factor.

A capacity factor (CF) taken from table 3-1 is used to make allowances for population variation, changes in sewage characteristics, and unusual peak flows. The design population is derived by multiplying the actual authorized military and civilian personnel population (called the effective population) by the appropriate capacity factor. Where additions are proposed, the adequacy of each element of the plant will be checked without applying the capacity factor. When treatment units are determined to be deficient, then capacity factors should be used to calculate the plant capacity required after expansion. However, the use of an unnecessarily high CF may so dilute waste as to adversely effect some biological processes. If the area served by a plant will not, according to the best current information, be expanded in the future, the capacity factor will not be used in designing treatment components in facilities serving that area. The following equation may be used to estimate total flow to the sewage plant where domestic, industrial and storm water flows are anticipated.

$$x = a + b \quad \text{(eq. 3-1)}$$

Where

x = Total flow to sewage plant

a = Flow from population (effective population x 100 gpcd x capacity factor

b = Infiltration + industrial wastewater + storm water (4 x dry-weather flow)

3-7: Hydraulic Capacity

3-7-1: Flow Definitions and Identification

The following flows for the design year shall be identified and used as a basis for design for sewers, lift stations, wastewater treatment plants, treatment units, and other wastewater handling facilities. Where any of the terms defined in this Section are used in these design standards, the definition contained in this Section applies.

a. **Design Average Flow**

The design average flow is the average of the daily volumes to be received for a continuous 12 month period expressed as a volume per unit time. However, the design average flow for facilities having critical seasonal high hydraulic loading periods (e.g., recreational areas, campuses, industrial facilities) shall be based on the daily average flow during the seasonal period.

a. **Design Maximum Day Flow**

The design maximum day flow is the largest volume of flow to be received during a continuous 24 hour period expressed as a volume per unit time.

C. Design Peak Hourly Flow

The design peak hourly flow is the largest volume of flow to be received during a one hour period expressed as a volume per unit time.

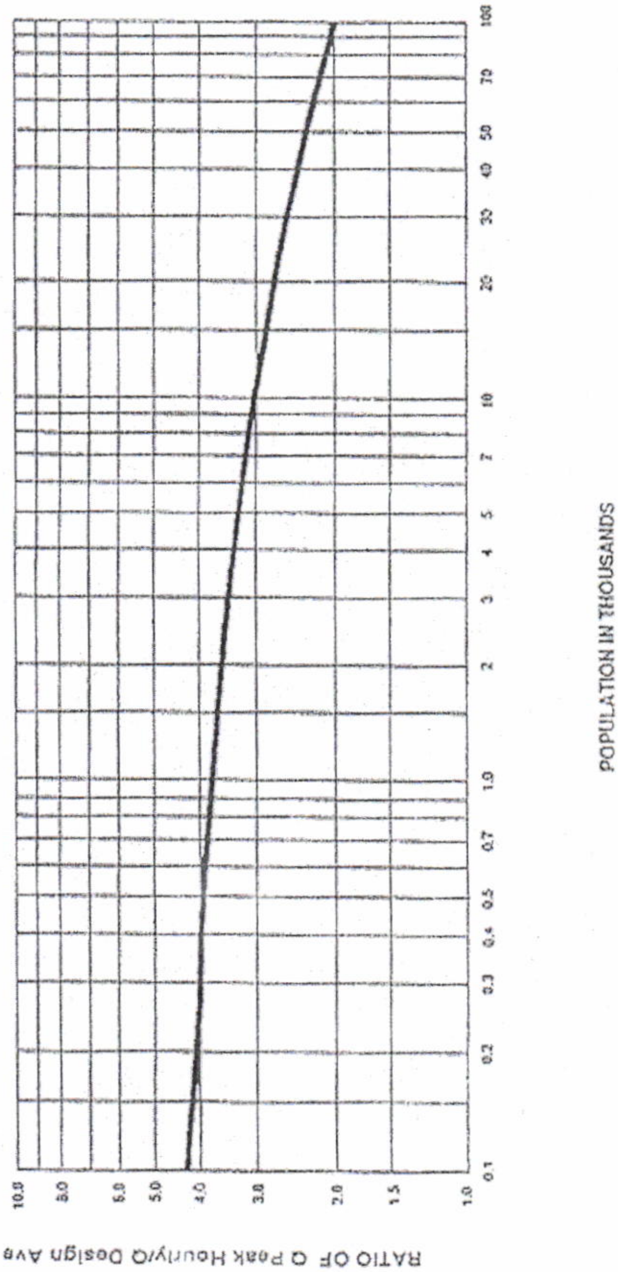
d. Design Peak Instantaneous Flow

The design peak instantaneous flow is the instantaneous maximum flow rate to be received.

3-7-2: Hydraulic Capacity for Wastewater Facilities to serve Existing Collection Systems

a. Projections shall be made from actual flow data to the extent possible.

FIGURE (3-2)
RATIO OF PEAK HOURLY FLOW TO DESIGN AVERAGE FLOW



Q peak hourly: Maximum Rate of Wastewater Flow (Peak Hourly Flow)

Q design ave: Design Average Daily Wastewater Flow

$$\text{Q Peak Hourly/Q Design Ave} = \frac{18 + \sqrt{P}}{4 + \sqrt{P}} \quad \ldots \quad (P = \text{population in thousands})$$

Source: Fair, G.M. and Geyer, J.C., "Water Supply and Waste-water Disposal" 1st Ed., John Wiley & Sons, Inc., New York (1954), p. 136

b. The probable degree of accuracy of data and projections shall be evaluated. This reliability estimation should include an evaluation of the accuracy of existing data, as well as an evaluation of the reliability of estimates of flow reduction

anticipated due to infiltration/inflow (I/I) reduction or flow increases due to elimination of sewer by passes and backups.

c. Critical data and methodology used shall be included. It is ecommended that graphical displays of critical peak wet weather flow data .

3-7-3: Hydraulic Capacity for Wastewater Facilities to serve New Collection Systems.

a. The sizing of wastewater facilities receiving flows from new wastewater collection systems shall be based on an average daily flow of 100 gallons (0.38 m^3) per capita plus wastewater flow from industrial plants and major institutional and commercial facilities unless water use data or other justification upon which to better estimate flow is provided.

b. The 100 gpcd figure shall be used which, in conjunction with a peaking factor from Figure (3-2) , is intended to cover normal infiltration for systems built with modern construction techniques. Refer to Section 31. However, an additional allowance should be made where conditions are unfavorable.

C. In the new collection system is to serve existing development the likelihood of I/I contributions from existing service lines and non- wastewater connections to those service lines shall be evaluated and wastewater facilities designed accordingly.

- Combined/Sewer Interceptors

In addition to the above requirements, interceptors for combined sewers shall have capacity to receive sufficient quantity of combined wastewater for transport to treatment facilities to insure attainment of the appropriate water quality standards.

CHAPTER FOUR

Chapter Four

Design Criteria of Bar Screens

4-1: Bar Screens

a) Description and function. The primary function of coarse screening is protection of downstream facilities rather than effective removal of solids from the plant influent. All screens used in sewage treatment plants or in pumping stations may be divided into the following classifications:

1) Trash racks, which have a clear opening between bars of 1-1/2 to 4 inches and are usually cleaned by hand, by means of a hoist, or possibly by a power-operated rake.

2) Standard mechanically cleaned bar screen, with clear openings from 1/2 to 1-1/2 inches (figure 4-1).

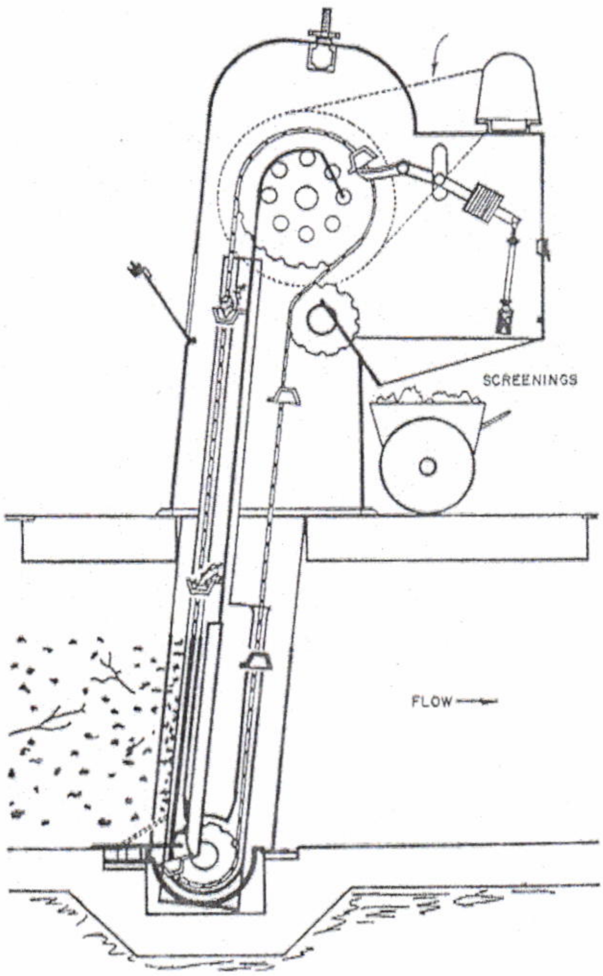
3) Fine screen, with openings 1/4 inch wide, or smaller.

b) Design basis. Screens will be located where they are readily accessible. An approach velocity of 2 fps, based on average flow of wastewater through the open area, is required for manually cleaned, bar screens. For mechanically cleaned screens, the approach velocity will not exceed 3.0 fps at maximum flows.

1) Bar spacing. Clear openings of 1 inch are usually satisfactory for bar spacing, but 1/2 to 1-1/2 inch openings may be used. The standard practice will be to use 5/16-inch by 2-inch bars up to 6 feet in length and 3/8-inch by 2-inch or 3/8-inch by 2-1/2-inch bars up to 12 feet in length. The bar will be long enough to extend above the maximum sewage level by at least 9 inches.

2) Size of screen channel. The maximum velocity through the screen bars, based on maximum normal daily flow, will be 2.0 fps. For wet weather

flows or periods of emergency flow, a maximum velocity of 3.0 fps will be allowed. This velocity will be calculated on the basis of the screen being entirely free from debris. To select the proper channel size, knowing the maximum storm flow and the maximum daily normal flow, the procedure is as follows: the sewage flow (mgd) multiplied by the factor 1.547 will give the sewage flow (cfs). This flow in cfs divided by the efficiency factor obtained from table 4-1 will give the wet area required for the screen channel. The minimum width of the channel should be 2 feet, and the maximum width of the



Envirex Inc. (Non copyrighted)

Figure 4-1.Schematic of Heavy Duty Mechanically Cleaned Bar Screen

Channel should be 4 feet. As a rule it is desirable to keep the sewage in the screen channel as shallow as possible in order to keep down the head loss through the plant; therefore, the allowable depth in the channel may be a factor in determining the size of the screen. In any event, from the cross-sectional area in the channel, the width and depth of the channel can be readily obtained by dividing the wet area by the depth or width, whichever is the known quantity.

Table 4-1.Efficiencies of Bar Spacing

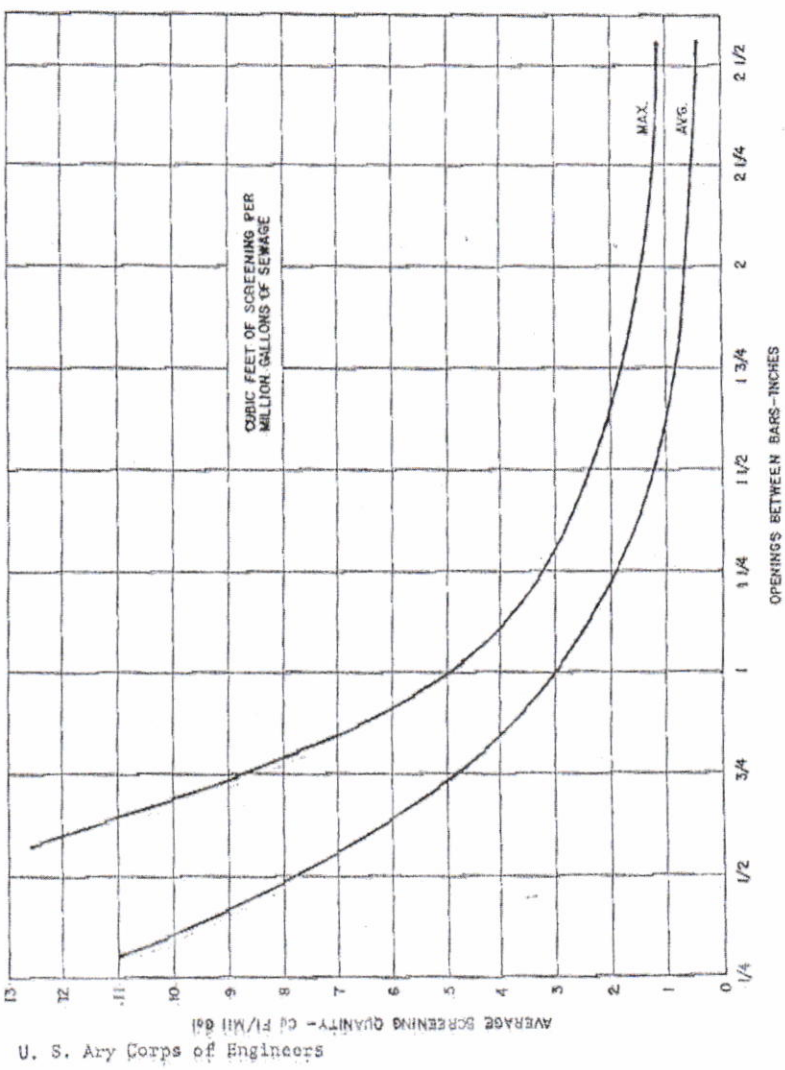
Bar Size	Openings	Efficiency
Inches	**Inches**	
1/4	1	0.800
5/16	1	0.768
3/8	1	0.728
7/16	1	0.696
1/2	1	0.667

3) Velocity check. Although screen channels are usually designed on the basis of maximum normal flow or maximum storm flow, it is important to check the velocities which would be obtained through the screen from minimum or intermediate flows. The screen will be designed so that at any period of flow the velocities through the screen do not exceed 3 fps under any flow condition.
4) Channel configuration. Considerable attention should be given to the design of the screen channel to make certain that conditions are as favorable as possible for efficient operation of the bar screen. The channel in front of the screen must be straight for 25 feet. Mechanical screens with bars inclined at an angle of 15 degrees from the vertical will be installed.
5) Screenings. The graph shown in figure 4-2 will be used to predict the average amount of screenings that will be collected on the bar screen.

The information required to make this estimate is flow and bar spacing. Grinding of the screenings (and returning them to the wastewater flow), incineration, and land filling operations are satisfactory methods for disposal of the screenings.

6) Design procedure. Select bar size and spacing and determine efficiency factor. Determine number of units desired. Divide total maximum daily flow or total maximum storm flow by the number of screens desired to obtain maximum flow per screen. The procedure is then as follows:

Maximum daily flow in $mgd \times 1.547$ = maximum daily flow in cfs.
Maximum storm flow in $mgd \times\times 1,547$ = maximum storm flow in cfs.



U. S. Ary Corps of Engineers

Figure 4-2 Estimate of Screening collected on Bar Screens

$\frac{cfs}{2}$ = net area through bars for maximum daily flow.

$\frac{cfs}{3}$ = net area through bars for maximum storm flow.

Whichever of the above gives the larger value should be used for design.

$$\frac{\text{Net area in square feet}}{\text{Efficiency coefficient for bars}} = \text{gross area or channel cross} - \text{ section wet area}$$

Minimum width of bar rack = 2 feet; Maximum width = 4 feet

$$\frac{\text{Channel cross} - \text{section wet area}}{\text{Maximum desired width or depth}} = \text{Corresponding depth or width}$$

These figures are based on recessing channel walls 6 inches each side for chain tracks and screen frame. The overall width of screen frame is 12 inches greater than width of bar rack. If not possible to recess walls, the channel should be made 1 foot wider than figured above.

(7) Sample calculation. Assume:

Maximum daily flow = 4 mgd

Maximum storm flow = 7 mgd

Maximum allowable velocity

through bar rack for

maximum daily flow = 2 fps.

Then, using the design procedure in the preceding paragraph :

Maximum daily flow = $4 \times 1.547 = 6.188$ cfs.

Maximum storm flow = $7 \times 1.547 = 10.829$ cfs.

Since $Q = Av, 6.188 = A \times 2$, and the net area A through the bars is 3.094 square feet. For a maximum allowable velocity through the bar rack of 3 fps during maximum storm flow, the net area through the bars must be $10.829/3 = 3.61$ square feet. The gross area will be based on the larger of the two net areas, in this case 3.61 square feet. A rack consisting of 2-inch by 5/16-inch bars spaced to provide clear openings of 1 inch has an efficiency of 0.768 (table 4-1), yielding:

Gross Area $= \frac{3.61}{0.768} = 4.70$ square feet

The channel width in this case might be established at 3 feet, in which case the water depth would be $4.70/3.0 = 1.57$ feet. This is a theoretical water depth which may be affected by subsequent plant units. The head loss through a bar rack is computed from the following equation:

$$h = \frac{V^2 - v^2}{45}$$

h = head loss in feet

V = velocity through rack

v = velocity upstream of rack

or:

$$h = 0.0222\,(V^2 - v^2)$$

Again making use of Q = Av,

$$v = 10.829/4.70 = 2.3\,fps$$

Therefore:

$$h = 0.0222\,(3^2 - 2.3^2)$$
$$= 0.222 \times 3.7$$
$$= 0.082 \text{ foot, or approximately 1 inch}$$

If the screen is half plugged with screenings, leaves, and other debris: From Q = Av the area is directly proportional to the velocity. In other words, if the area is cut in half, the velocity must double. The head loss therefore is:

$$h = 0.0222\,(6^2 - 2.3^2)$$
$$= 0.0222\,x\,30.7$$
$$= 0.682 \text{ foot, or approximately } 8 - 1/4 \text{ inch}$$

The increase in head loss is over one-half foot as the screen becomes half plugged. The need for accurate control of the cleaning cycle, and protection against surge loads, is thus demonstrated.

CHAPTER FIVE

Chapter 5

Design of Bar Racks

5-1: calculation of design flow:

$$- \ avarage\ Flow = \frac{Population * {}^{l}/_{c.d}}{24*3600}$$

$$- \ let\ P = 50000$$

$$\text{Av. Flow} = \frac{50000*450}{24*3600^{s}/_{d}} = 260.4 = \ell/s = 0.261\ m^3/s$$

$$- \ Max\ Flow = av.Flow * factor$$

$$factor = \frac{18 \pm \sqrt{P}}{4 + \sqrt{P}} = \frac{18 \pm \sqrt{50}}{4 + \sqrt{50}} \quad f = 2.26 \qquad \cong 2.3$$

$$-Max\ dry\ wather\ Flow = 0.61 * 2.3 = 0.59104\ m^3/s$$

$$-Peak\ Flow\ (\ wet\ weather\ Flow\ ) =$$

$$Max\ dry\ wather + Infiltration/in\ Flow$$

$$Infiltration/in\ Flow\ I/I = \frac{Population * I/I\ Flow\ all}{24 * 3600}$$

$$I/I = \frac{50000 * 437}{24 * 3600} = 252.89 = 0.252\, m^3/s$$

$$-Peak\ Flow = 0.25289 + 0.59104 = 0.843933\ m^3/s$$

5-2: Assumption

a) Two I identical Bar racks.

b) Mechanical cleaning device

Table (5 – 1) : design factors for Manually and Mechanically cleaned bar racks.

Design factor	Manually cleaned	Mechanically cleaned
Velocity m/s	**0.3 -0.6**	**0.6 -10**
Bar size **-width , mm** **-depth ,m m**	 **4 – 8** **25 -50**	 **8 -10** **50 - 75**
Clear spacing between bars ,m m	**25 -75**	**10 -50**
Slope from horizontal (degree)	**45 - 60**	**75 - 85**
Allowable head loss clogged screen (mm)	**150**	**150**
Maximum head loss clogged screen (mm)	**800**	**800**

c) Slop from horizontal 75 (From table (5-1)).

d) Bar spacing (clear) = 2.5 cm (From table (5-1)).

e) The velocities through rack are between (0.3 – 1.0 m / sec)

- $V = 0.9\ m/s\ \rightarrow for\ peak\ design\ wet\ weather\ flow$
- $V = 0.6\,m/s\ \rightarrow for\ Max\ design\ wet\ weather\ flow$
- $V = 0.4\,m/s\ \rightarrow for\ average\ design\ wet\ weather\ flow$

5-3: Calculations of flow conditions in the incoming pipe to the screen

-The incoming pipe to the screen is show in Fig .(5-1)

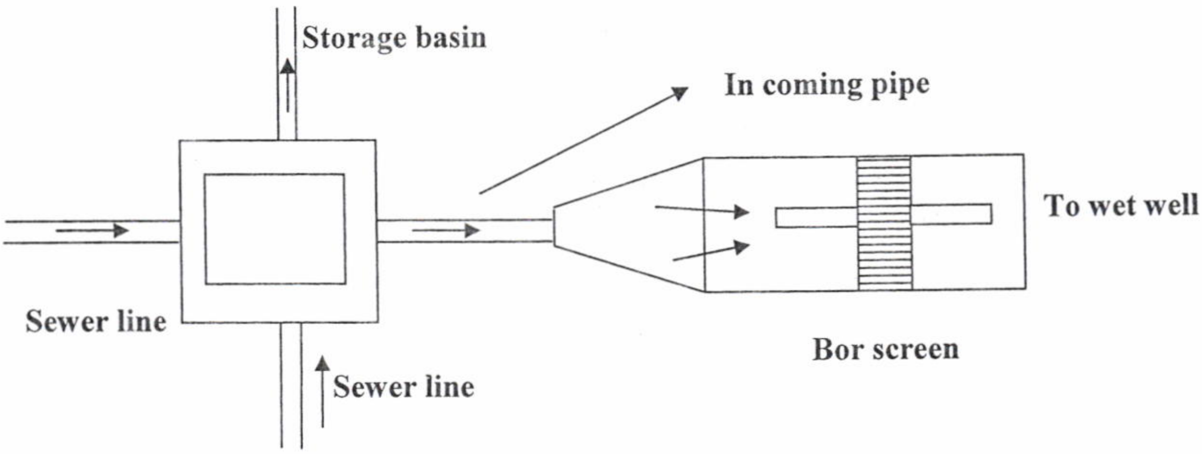


Fig. (5-1): Sewer and Bar screen layout

- A good practice is to maintain velocity above 0.3 m/s for sanitary sewer under low- flow conditions. Under peak dry weather condition $V > 0.06 \left(use\ V = 0.8 \frac{m}{sec} \right)$.
- Dia of incoming pipe:

$$Q_{Peak\ (wet)} = V * A$$

$$\therefore 0.85\ m^3/s = 0.6\ m/s * \frac{\pi}{4} D^2$$

$$D = 1.34\ m$$

- Depth of flow in the pipe (partial flow):

$use\ n = 0.015$

$s = 0.0005$

$$Q_{full} = \frac{1}{n} R_{D/4}^{2/3} A S^{1/2}$$

$$= \frac{1}{0.015} * \left(\frac{1.34}{4}\right)^{2/3} * \frac{\pi + 1.34^2}{4} * 0.0005^{1/2}$$

$Q_{full} = 1.014$

From Fig. (5-2)

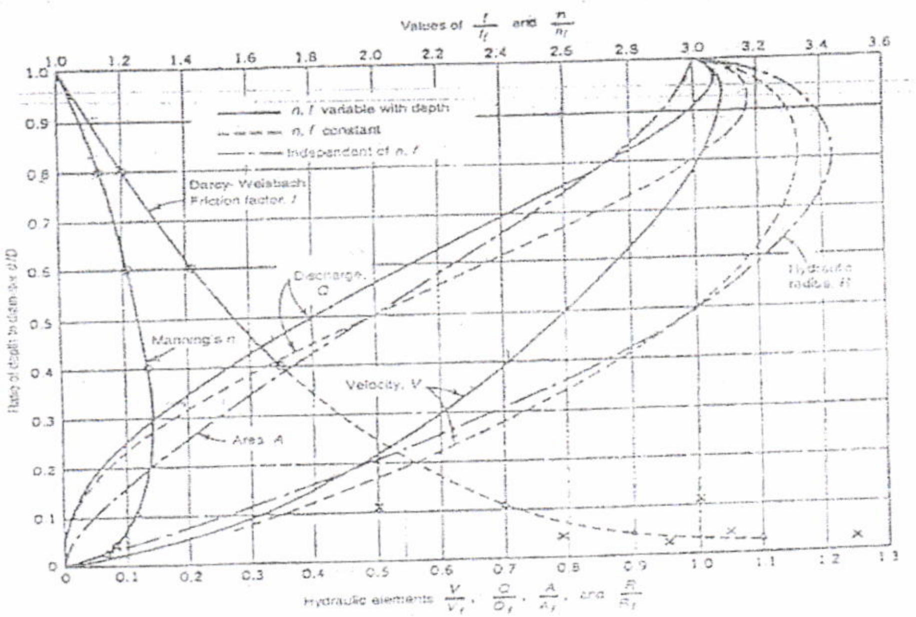
- $\frac{Q_{Peak}}{Q_{full}} = \frac{0.85}{1.014} = 0.83$

-From fig. $\frac{d}{D} = 0.78$

- $\frac{V}{V_{full}} = 0.99$

- $\frac{d}{D} = 0.78 \rightarrow d = 0.78 * 1.34$

- $d = 1.045$



Hydraulic elements of a circular pipe.

Fig. (5-2) :Hydraulic elements of circular pipe

5-4: Design of rack (screen) chamber

5-4-1: Compute bar spacing and the dimensions of the bar rack chamber.

- The rack chamber is designed for peak wet weather flow.
- The depth of flow in the rack chamber = 1.045 depth of flow in the pipe at peak design flow.

a. $Clear\ area\ through\ the\ rack\ openings = \frac{Peak\ desgin\ flow}{Velocity\ through\ rack}$

$$= \frac{0.85}{0.6} = 1.42\ m^2$$

b. $clear\ width\ of\ the\ opening\ at\ the\ rack = \frac{area}{depth\ of\ flod}$

$$= \frac{1.42}{1.045} = 1.35$$

c. Provide 50 clear spacing at (10-50) mm take an average (30m m) from table.(5-1)

d. $Total\ width\ of\ the\ rack\ chamber\ = 50 * 30mm$

$$Clear\ width\ = 1.5\ m$$

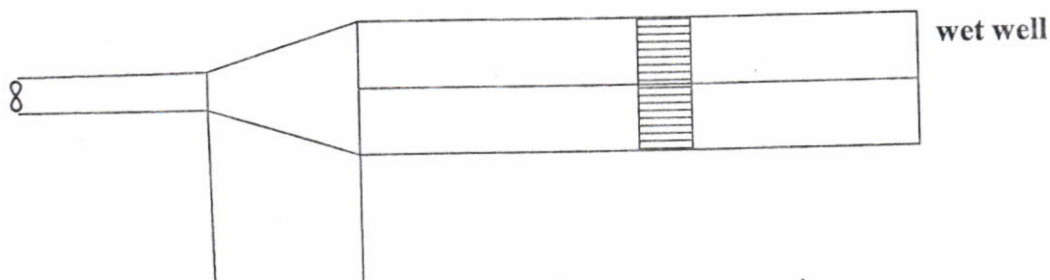
e. $Total\ number\ of\ bors\ = N.of\ clear\ spacing - 1$

$$50 - 1 = 49$$

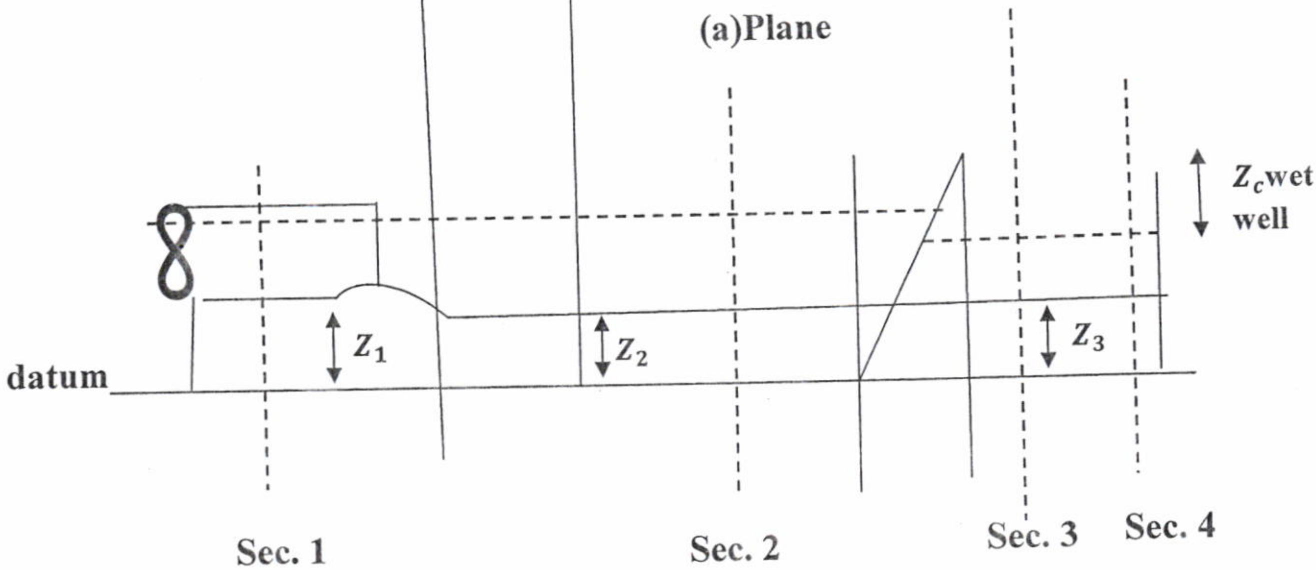
f. Provide bars with (8-10)mm width, take 10mm (from table (5-1))

g. $Width\ of\ chamber\ = 1.5m + 10mm * \frac{49}{1000} = 1.99m$

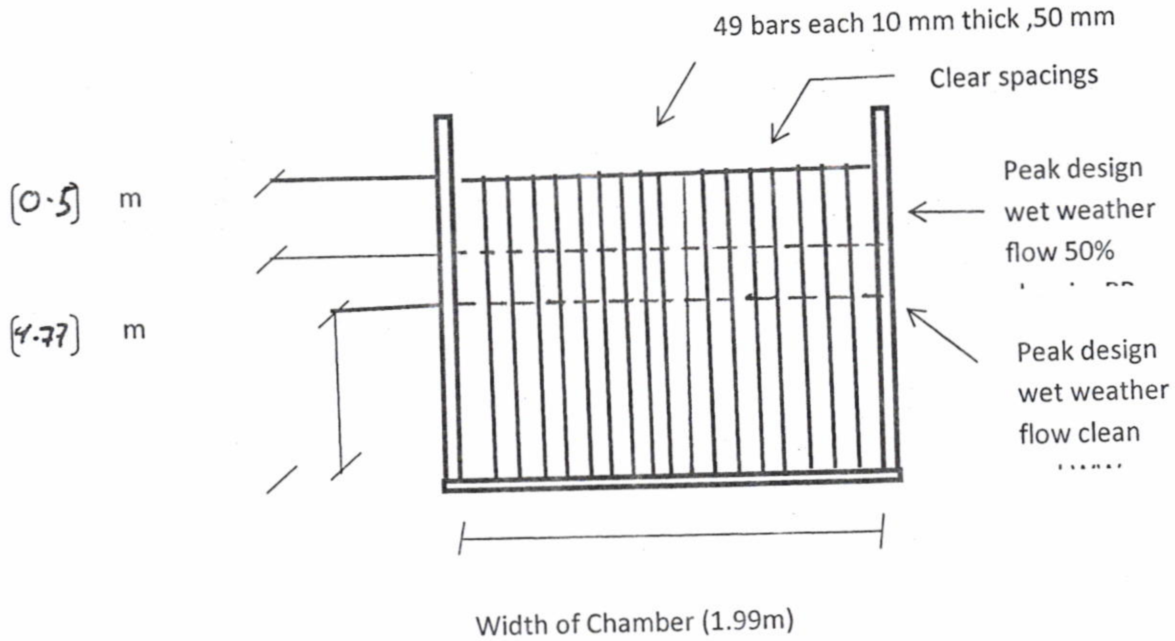
h. The plan longitudinal section the cross section of the chamber of are shown below .Fig. (5-3).



(a)Plane



(b) Longitudnail Section through the rack chamber



Width of chamber (1.99 m)

C) cross section showing bar arrangement

Fig (5-3) I Details of rack chamber .(a, b and c)

<u>5-4-2: Compute the actual depth of flow and velocity in the Rack chamber at peak design flow</u>

Energy eq. between sec1 and sec2

$$Z_1 + d_1 + v_1^2/2g - hL = Z_2 + d_2 + v_2^2/2g$$

hL=$Ke(v_1^2/2g - v_2^2/2g)$

Where Ke = coefficient of expansion (0.2 -1.0)

Use Ke =0.3

$$Z_1 - Z_2 = 10\ cm = 0.1$$

0.1+ d +V^2covzdit/2g

$$= d_2 + \left(\frac{\frac{Qpeak}{widthofthechamber * d_2}}{2g}\right)^2 + 0.3\left(\frac{Vcovzdit}{2g} - \frac{(Qpeak/width * d_2)^2}{2g}\right)$$

$$0.1 + 1.045 + \frac{0.6}{2 * 9.81} = d_2 + \left(\frac{\frac{0.85}{1.79 * d_2}}{2 * 9.81}\right)^2 + 0.3\left(\frac{0.6}{2 * 9.81} - \frac{(0.85/1.79 * d_2)^2}{2 * 9.81}\right)^2$$

(1.165= d2+86.787/d2^2+0.09-2.6/d2^2) *d2^2

d2-1.085 d2+84.187=0

$d = 1.15m$

$$v_2 = \frac{Qpeak}{width * d_2} = \frac{0.85}{1.79 * 1.15} = 0.41$$

<u>5-4-3 Compute the velocity through the clear openings of the bar rack</u> :

$$v = \frac{flow}{nat\ crea\ at\ the\ rack} = \frac{Q\ peak\ m^3/s}{clean\ width\ of\ the\ opening\ of\ the\ rack * d_2}$$

$$= \frac{0.85}{2.35 * 1.15} = 0.31 \text{ m/s}$$

<u>5-4-4: Compute head loss through the bar rack</u>

$$hL_1 = \frac{v^2 - v_v^2}{2g}\left(\frac{1}{0.7}\right) \text{... for portly clogged bars}$$

$$hL_2 = \beta\left(\frac{W}{b}\right)^{4/3} \text{hv } \sin\theta \text{ ... for clean screen}$$

Where hL = head losses through the rack , m

V,V_v = velocity through rack and in the channel u/s of the rack

w= Max .cross – sectional width of the bars facing the direction of flow , m

b= Min – clean spacing of bars ,m

hv=Velocity head u/s of the bar

θ= angle of bars with horizontal (75-85) from taple

β=bar shape factor (0.76 – 2.42)

$$hL_1 = \frac{0.62 - 0.1}{2 * 9.81} * \frac{1}{0.7} = 0.037 \text{ m}$$

$$hL_2 = 2.42 * \left(\frac{49 * 10 \text{ mm}}{45 * 30}\right)^{4/3} * \frac{0.62}{2 * 9.81} * \sin 75 = 0.026 \text{ m}$$

Use hL=0.037 m

<u>5-4-5: Compute the depth of flow and velocity in the rack chamber below the rack d_3, v_3</u>

Energy eq. between sec .2 and sec .3

$$d_2 + \frac{v_2^2}{2g} - \text{hL} = d_3 + v_3^2/2g$$

$$1.15 + \frac{0.41^2}{2 * 9.81} - 0.037 = d_3 + \frac{(0.85/d_3 * 1.79)^2}{2 * 9.81}$$

$$4.739 = d_3 + \frac{0.11}{d_3^2} * d_3^2$$

$$d_3^3 - 4.739\, d^2 + 0.11 = 0$$

By trial and error

d_3= 1.12 m

v_3= 0.71 m / sec

<u>5-4-6: Compute the head loss through the rack at 50% clogging</u> .

a) Energy eq.:

$$d_2' + \frac{v_2'^2}{2g} = d_3 + \frac{v_3^2}{2g} + \text{h50}$$

d_2' and v_2' = depth of flow and velocity in the clamper u/s of the rack at 50% clogging

H50=head loss through the rack at 50% clogging

b) $h50 = \frac{Vrackopening - v_2'^2}{2g} * \frac{1}{0.7}$

c) $Vrack_{opening} = \frac{Q}{A} = \frac{Q\ peak}{clear\ width\ of\ the\ opening\ at\ the\ rack * 0.5 * d_2'}$

$$= \frac{0.85}{1.33 * 0.5 * d_2'} = \frac{1.25}{d_2'}$$

d) $v_2' = \frac{Q\ peak}{width\ of\ the\ chamber * d_2'} = \frac{0.85}{1.79\ d_2'} = \frac{0.475}{d_2'}$

e) $d_2' = \frac{\frac{0.475}{d_2'}}{2*9.81} = d_3 + v_3^2/2g + \frac{\left(\frac{1.15}{d_2'}\right)^2 - \left(\frac{0.475}{d_2'}\right)^2}{2*9.81*0.7}$

$$d_2' = \frac{0.0242}{d_2'} = 1.12 + 0.249 + \frac{0.097}{d_2'} * d_2'^2$$

$$d_2'^3 - 0.29742 d_2'^2 - 0.0728 = 0$$

By trial and error

$d_2' = 1.18$ m

$$v_2' = 0.57\ m/s$$

$$V\ rack\ opeing\ 50\%\ \text{clogging}\ is = \frac{1.25}{1.18} = 1.059\ m/s$$

H50=0.19 m

5-5: Bottom Slope of the channel Below the Rack :-

5-5-1: Compute the critical depth of flow :

a) **For Rectangular channel critical depth .Fr=1**

$$Q = Av = Ac\sqrt{gde} = b\sqrt{g}\,dc^{3/2}$$

b) at peal design flow (0.85) m³/ sec and channel Width of chamber 1.35m

$$dc = \left(\frac{Qpeak}{b\sqrt{g}}\right)^{2/3} = \left(\frac{0.85}{1.79\sqrt{9.81}}\right) = 0.28 \text{ m}$$

c) Vc= critical velocity $= \frac{Qpeak}{b\ chember * dc} = 1.64\ m/s$

d) the critical depth generally occurs at a distance (3-10) * dc from the point of free fall

5-5-2: Calculate the elevation of the channel bottom near free fall in the wet well :

a) Use Energy eq. between sec (3) and sec (4)

$$Z_3 + d_3 + \frac{V_3^2}{2g} - hL = (Z_3 + Z_c) + dc + \frac{V_c^2}{2g}$$

b) Neglect friction losses , so

$$0 + d_3 + \frac{V_3^2}{2g} = +dc + \frac{V_c^2}{2g}$$

$$0. + 1.12 + \frac{4.9^2}{2 * 9.81} = Z_c + 0.28 + \frac{1.85^2}{2 * 9.81}$$

$\therefore Z_c = 0.69$ m (the floor of the channel is raised by 0.69 m)

5-6: Hydraulic profile through the bar Rack assume channel floor is 0.00

Fig (5-4) Hydraulic profile through the Bar Rack

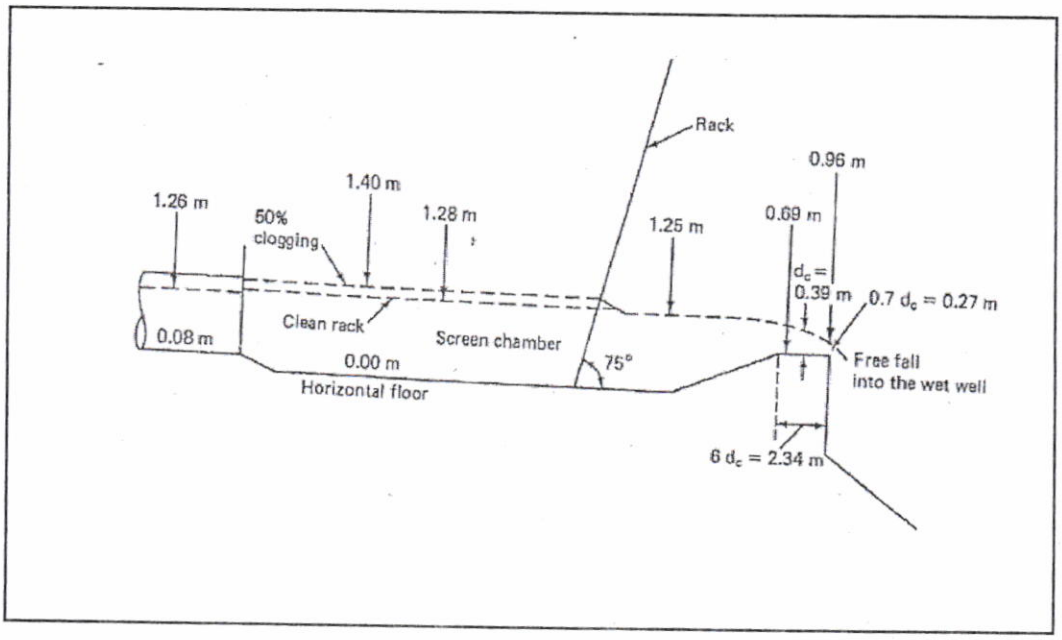


Fig. (5-4) hydraulic profile through the Bar Rack

5-7: Quantity of screenings :

- The quantity of screenings is botanical from the Fig. (5-5) below :

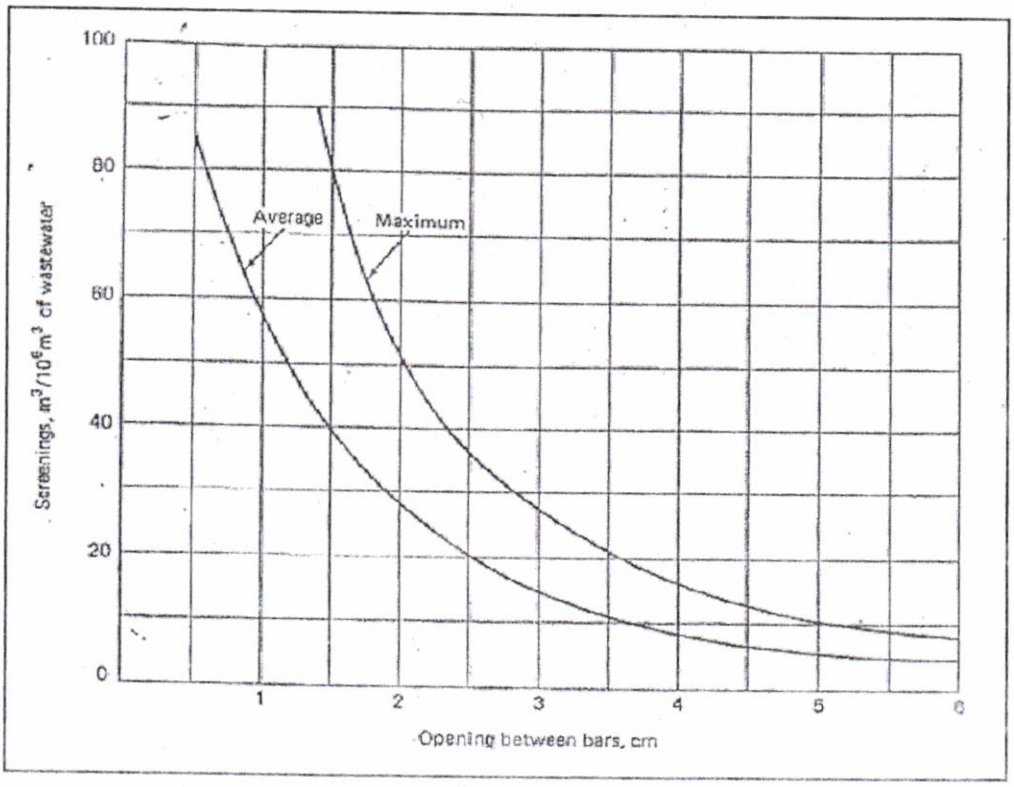


Fig. (5-5) The relationship between of opening of bars and the screenings

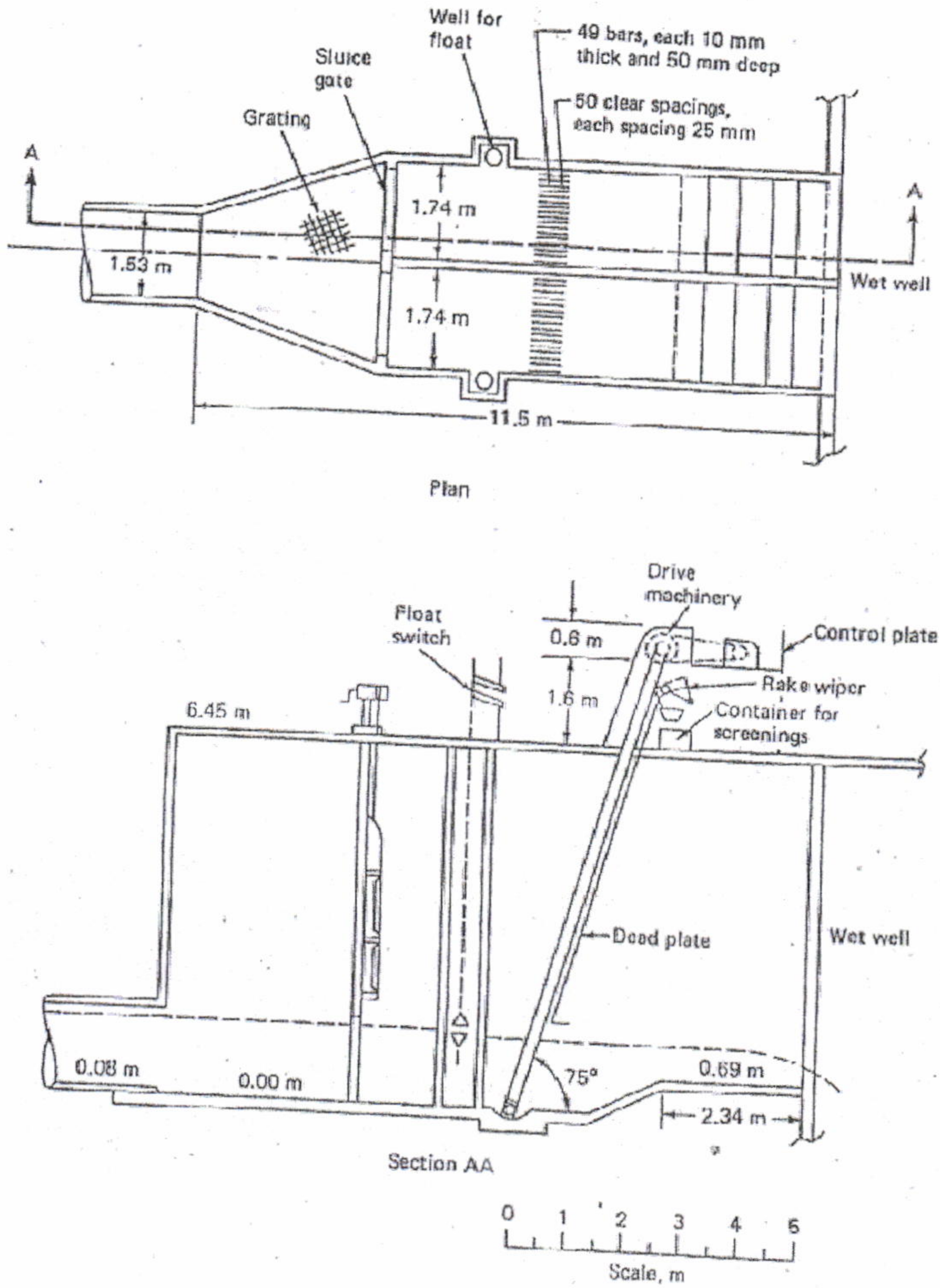


Fig . (5-6) Design details of the bar rack

Conclusion:

1- The rack chamber is designed for peak wet weather flow .

2- The velocities through the rack and channel and depth of flow in the channel are checked for average and minimum design flows.

3- Bar spacing and the head loss constraints through the rack and through the entire plant.

4- The velocity and depth of flow in the channel below the rack are governed by the condition in the outlet channel (the channel that carries the screened waste water).

5- If the large objects is not removed by screening , these objects may damage the pumping ,block valves ,nozzles ,channels and pipe.

6-The design for bar racks are the velocity ,bar size ,clear spacing between bars ,slope of the channel ,head losses through the racks.

7- The total number of bars was (49).

8- The with of the chamber was (1.99) m.

9- The difference between the depth of flow u/s and d/s of the rack was (   ) cm.

10-The quantity of screening was (9396) m/d.

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