DESIGN, FABRICATION AND INSTALLATION TECHNIQUES FOR TRASH RACKS

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
WATER RESOURCES DEVELOPMENT
(MECHANICAL)

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled "DESIGN, FABRICATION AND INSTALLATION TECHNIQUES FOR TRASH RACKS", in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Water Resources Development (Mechanical), submitted in the Water Resources Development Training Centre, Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during the period July 15th 2003 to June 15th 2004 under the supervision of Dr. B.N. Asthana, Visiting Professor, and Professor Gopal Chauhan, Professor WRDTC, Indian Institute of Technology Roorkee, India.

I have not submitted the matter embodied in this thesis for the award of any other degree.

Date : June 23, 2004
Place : Roorkee

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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SYNOPSIS

Trash rack for the intake of a hydroelectric development is an important item. The function of the trash rack is to keep out debris and other materials including fish carried by water which are likely to damage or otherwise render inoperative the control equipment's or the turbines.

Design criteria for trash rack structure, fabrication and installation has been discussed in this dissertation. For overall economy of the design, various aspects like velocity of water, spacing and shape of bars, their vibration, head losses, cleaning arrangement have been considered. Determination of clear spacing between rack bars is important. This depends on the characteristics of the turbine to be protected and the nature of trash. As the spacing becomes closer the head loss increases. Hence the maximum allowable clear spacing should be determined. Determination of loss of head as per older formulae such as Kirschmer etc. gave lower values than the actual. Reason for this has been found to be due to not considering certain parameters which influence loss of head. An example using different formulae given by various authorities has been worked out to determine the best formula applicable. For right angle flow Berzinki's formula and for angular flow Ideltchik's formula have been found to be more accurate. Methods of minimizing loss of head considering economy have been given in detail.

In the structural design the effect of vibration is also considered, as otherwise bars may fail due to fatigue. Shapes of trash rack bars should be selected considering head loss, vibration and economy. Streamlined section which gives minimum loss of head is quite favorable as far vibration and economy is concerned.

Manufacturing aspects ranging from defects in welds to various methods of non-destructive testing (NDT) have also been covered as per relevant practices.

Finally, installation aspects ranging from embedded parts to trash disposal equipment all also presented.

All the above said aspects have been applied to various projects in Indonesia so as to have appreciation of the concepts from practical viewpoint.

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ACKNOWLEDGEMENT

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Roorkee, June 23, 2004

FACHRUDIN LEDDY

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LIST OF SYMBOLS

The following symbols are used in this dissertation:

A = $\frac{Net\,area}{Gross\,area}$

B = Width of entrance flume.

b = Clear spacing between the bars.

C = Constant

D = Thickness of trash rack bars.

d = Width of slot at right angle to flow direction.

E = Elastic modulus of the bar material.

e = Width of slot in the direction of flow.

f = Frequency.

f_f = Force frequency.

f_y = Yield stress.

f_n = Natural frequency.

g = Acceleration due to gravity.

H = Head of water.

H_b = Distance between bracing members.

h = Depth of entrance flume.

h_r = Head loss through rack.

I = Moment of Inertia.

K = Stress of concrete.

K_d = Coefficient of residual detritus.

K_f = Coefficient of form of section of the bar.

K_t = Factor depending on bar shape.

K_i = Ratio $\frac{b}{(t+b)}$.

L = Unsupported length of the bar.

M = Bending moment.

P = Hydraulic pressure.

p = Ratio of the solid area to total area of screen.

r = Radius of gyration of the normal selection of the bar in relation to the axis parallel to the velocity of the current.

S_t = Strouhal Number.

T = Tension.

t = Thickness of bar.

V = Velocity of water.

V_1 = Average velocity in the small section.

V_o = Approach velocity.

W = Hydraulic load.

W = Virtual weight.

w = Width of bar.

y = Specific gravity of steel.

y_1 = Specific gravity of water.

Z = Section modulus of rail.

α = Angle of the rack to the horizontal.

γ^b = Density of the bar material.

γ' = Fluid density.

θ = Horizontal angle, between the approach velocity and the exit velocity.

μ = The contraction coefficient.

σ = Bending stress.

σ_c = shear stress of concrete.

CHAPTER - I

INTRODUCTION

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INTRODUCTION

1.1 PROBLEMS OF TRASH AT INTAKES

Floating trash is generally encountered in varying amounts at all surface water intakes, often becoming a serious problem during floods. The trash carried by the flow may consist of a wide variety of drift wood including anything from logs and large trees to small twigs, miscellaneous refuse, grass various submerged vegetation and other floating or suspended matter, depending largely on the geographical locations. Plants near lumbering areas are usually troubled by debris from upstream logging operations. Other plants may have seasonal problems caused by large quantities of leaves floating on the water in the fall. Difficulties at intakes in cold climates may be created mainly by ice. At many plants heavy runs of trash may occur after weather disturbances such as windstorms or heavy rainfall, or due to temporary conditions such as construction operations upstream of intake.

1.2 TRASH RACK STRUCTURE

Trash Rack is a structure with its water passages protected with steel trash bars and forms an integral part of the intake structure of any water resources development project, including both irrigation and hydropower development projects. However, they assume higher importance for hydropower development projects because any trash passing into the water passages of turbines may result into severe damage. The function of the trash rack at intake is to guide water into the penstock or conduit under controlled conditions. Trash racks (also called rack and sometimes screens) to intercept material carried by the water, which may not be readily passed through the turbines are placed before the intake at the dam. In the case of a long canal, another set of trash racks may also be placed near its lower end. The trash racks are assembled into panels of convenient size, which are, supported on girders fixed at the intake as shown in Figure 1 – 1.

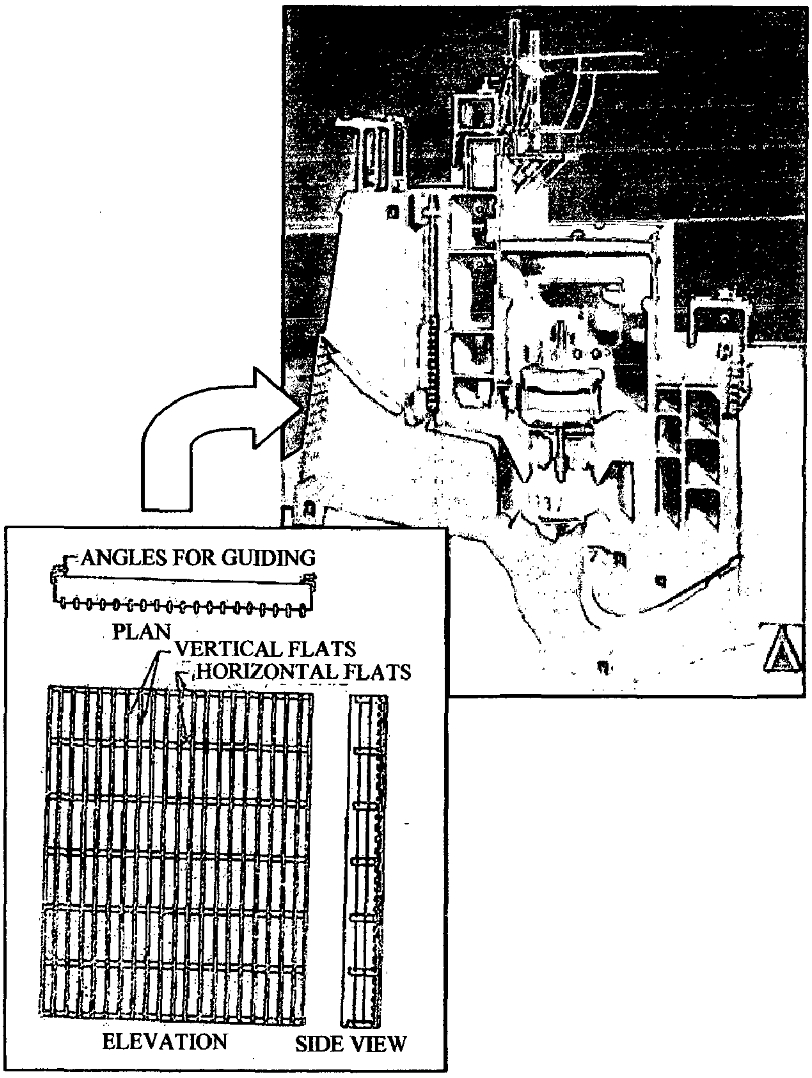

Figure 1 – 1 Trash Rack Arrangement.

Because of the presence of trash rack in flow path there is a loss of head and consequent loss of energy. This head loss will increase if the racks are clogged by trash or ice. A study of the operating records of several hundred hydroelectric stations in U.S.A. has indicated that unscheduled shutdowns due to severe trash or ice conditions at the racks averaged about 2% of their total outage time. However in some individual plants trash and ice accounted for 10% to 15% of the total outage time. It should be noted that these statistics indicated only the outage time due to complete shutdowns and did not reflect the reduction in plant capacity due to partial obstruction of flow through the racks. Loss of energy due to inadequate cleaning of the racks may reach 5% of annual generation or more, especially in low head plants. The importance of providing adequately designed, constructed and maintained trash racks cannot be overlooked in striving to minimize unscheduled interruptions and consequent loss of power generation.

Function of trash rack provided at the entrance of intakes is to protect turbines, pumps, gates, etc. from objectionably large debris. The layout of trash rack is shown in Figure 1 – 2. This study is limited to the trash racks for Hydro Electric Project Intakes.

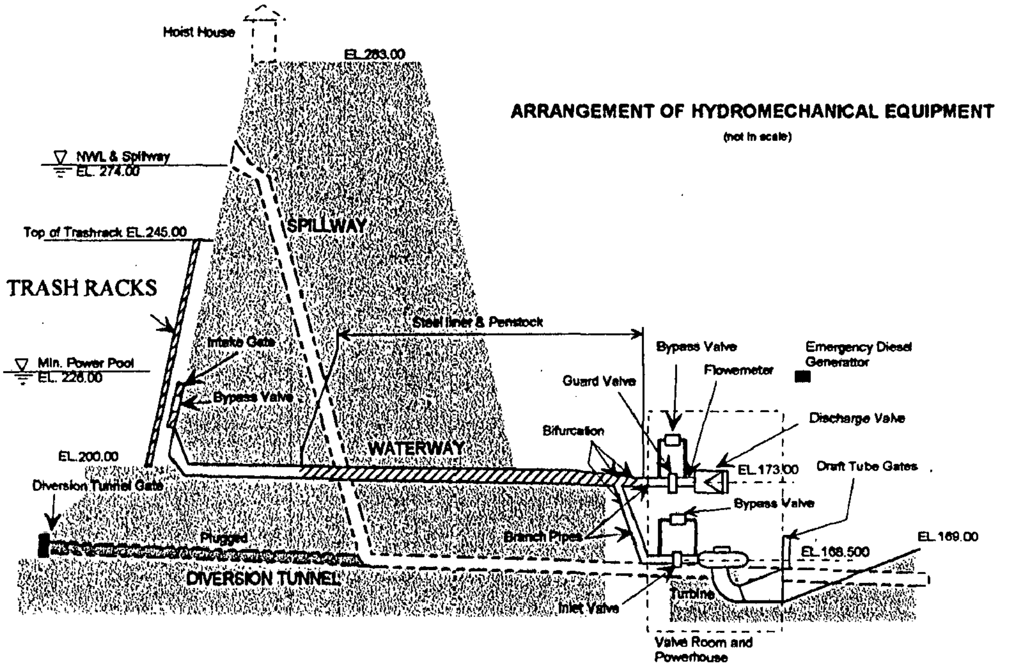

Figure 1 – 2 Arrangement of Trash Rack & Other Hydromechanical Equipment.

1.3 INPORTANCE OF TRASH RAKE CLEANING

To permit the plant operation at full capacity the trash racks must be kept clean and free of excessive accumulation of debris, which would obstruct flow. It is therefore necessary in most cases to provide suitable equipment for cleaning the racks and for the disposal of the trash. It must be kept in mind that the overall economy must be the major criteria. To some it might appear desirable to have all operations automatic; meanwhile others may desire to have much of the operations done by manual labor. The designer must provide features for the plant such that they result in the minimum annual charge.

E. Chapter five: installation.

In this chapter installation to comprise equipment requirement, flow chart of trash rack installation, and installation procedure for trash rack has been presented.

F. Chapter six: conclusion.

In this chapter conclusions from the study & recommendations for future work have been covered.

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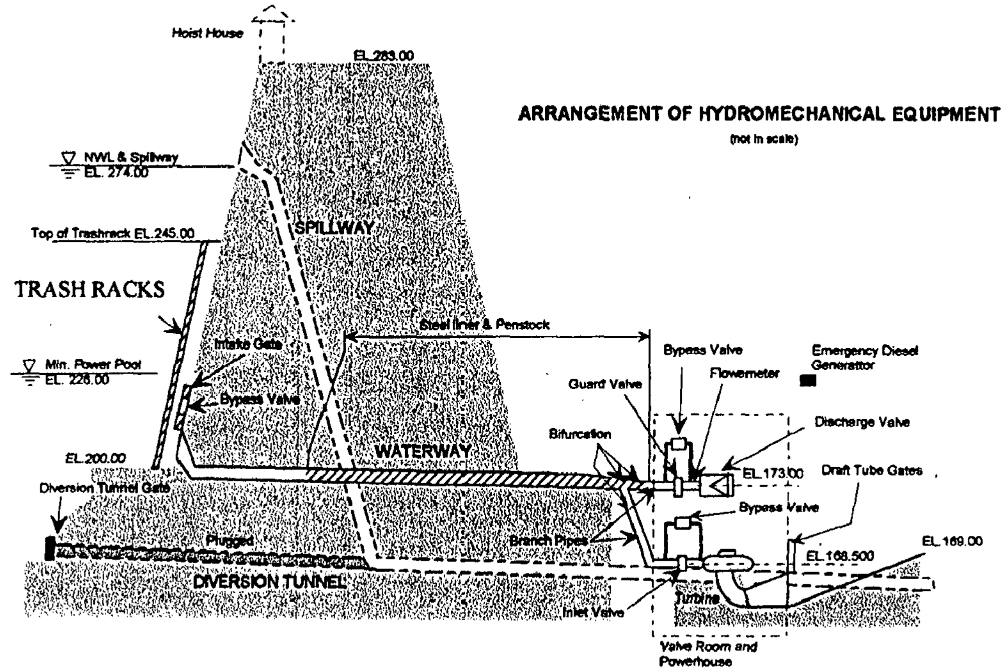

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1.4 SCOPE OF STUDY

The study includs Literature Review, Hydraulic & structural design of Trash Rack, Fabrication and Installation of trash rack. The parameters involved in the study of a trash rack are as follows. A suitable velocity through racks and the shape of bars are to be selected considering the problem of vibration of bars, minimizing head loss and the economy of the structure.

The clear spacing between bars should be such that the materials, which escape through the trash rack, should be able to safely pass through the waterways without damaging the equipment. As the loss of head should be minimized to the extent possible the spacing selected is to be the maximum permissible.

For estimating the head loss through trash rack, various parameters, which will affect the head loss, have been considered. Formulae for racks at right angels to the direction of flow and oblique to the direction of flow have been separately studied.

The design data for trash rack has been adopted from Batutegi Dam Project and conveyor belt data has been adopted from Sengguruh Hydropower Project in Indonesia. The study revealed that at least following parameters must be considered when designing trash rack, viz:

- Head loss across the screen plus head loss due to the accumulation of debris in submerged screens which is often taken as 6 m and is considered as design head.
- Spacing of screen bars, which depends on the minimum openings of turbines or pumps to pass solid objects is general taken as 100 mm, although 75 mm or less is sometimes used.
- Vibration.
- The trash rack cleaning is required to reduce loss of energy.

1.5 COMPOSITION OF THE THESIS

The composition of the report is as follows;

A. Chapter one: introduction.

This chapter covers definition of trash rack, problems at trash rack, importance of trash rack cleaning, and scope of study.

B. Chapter two: literature review.

Arrangement of trash rack to comprise: layout, trash rack structure, location of trash racks, type of trash rakes, and selection of type trash rack has been presented in this chapter.

The hydraulics of trash rack to comprise: velocity through trash rack, permissible velocity through trash rack, and head loss trough trash rack has also been discussed in this chapter, besides the structural design of trash rack to comprise: design head, design of trash rack bars, vibration, trash removal, inspection of rakes cleaning, and selection of trash rake cleaning.

C. Chapter three: design calculation of trash rack.

In this chapter bending moment and bending stress for trash rack bars, outer beams, and inner beams, have been computed along with hydraulic aspects of trash rack to comprise water velocity through trash rack, head loss through trash rack, and vibration, besides stress on rail and concrete, horizontal rack to comprise loading, bending moment, and bending stress on bars, and beams. Also, weight calculation for rake cleaning, trolley, and trash cage as well as design of flat belt conveyor to transport the rubbish has been presented in this chapter.

D. Chapter four: fabrication.

In this chapter process fabrication in accordance with working drawing, to comprise material requirement, equipment requirement, quantity to be prepared, defects in welds, flow chart of fabrication, inspection and testing of welds, and corrosion protection has been discussed.

E. Chapter five: installation.

In this chapter installation to comprise equipment requirement, flow chart of trash rack installation, and installation procedure for trash rack has been presented.

F. Chapter six: conclusion.

In this chapter conclusions from the study & recommendations for future work have been covered.

CHAPTER - II

LITERATURE REVIEW

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LITERATURE REVIEW

2.1 ARRANGEMENT OF TRASH RACKS

2.1.1 LAYOUT

All inlets to pensptocks, tunnels and outlets etc. have to be provided with trash racks for screening debris and other control equipments to control to flow. These mechanical equipments necessitate periodical attention and as such necessity is felt to provide an approach to the inlet. The inlets when located at the upstream face of a dam provide easy means of approach. However in the case of intakes located on the hill sides proper provision of approach depends upon the topography and geology of the site.

As has already been stated many considerations are taken into account when determining the position of an intake and hence the trash racks. When the trash rack at intake is arranged as part of a dam, the requirement of the intake should be considered while locating the dam. Where the trash rack at intake forms the entrance to a tunnel its position can be varied to a greater extent. The factors governing the arrangement of an intake include the following:

a) If possible the intake should be so aligned that the trash and ice tends to float past and not collect at the intake screens, as shown in Fig. 2 – 1.

b) On salmon rivers the smallest and kelts traveling downstream are guided by the flow towards the trash rack at intake. It should, therefore, be located as close as practicable to the fish pass at the dam or the smolt and kelt fall over weir.

c) If the trash rack at intake is well submerged the clogging of the racks due to collection of debris and floating matter is not likely but if the water level would fluctuate around the level of trash rack at intake, the collection of debris would be a serious problem, ref the river carries considerable debris and tree leaves. In this case the location of the intake should be given special consideration and trash booms should be provided where found necessary as shown in Fig. 2 – 2 below.

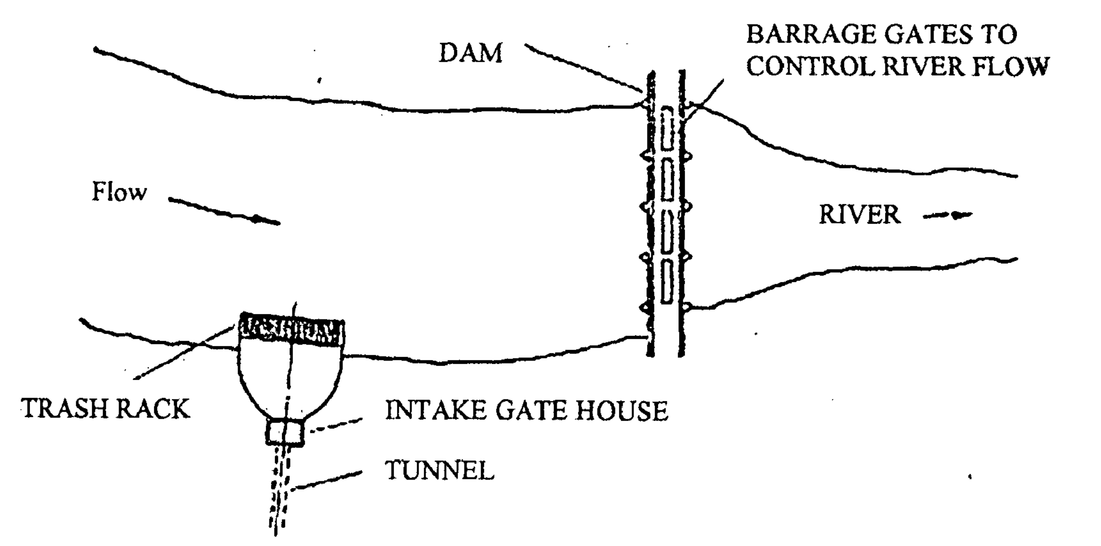


Figure 2 – 1 Intake Located so That River Flow Tends to Prevent Trash and Ice Collecting at Trash rack.

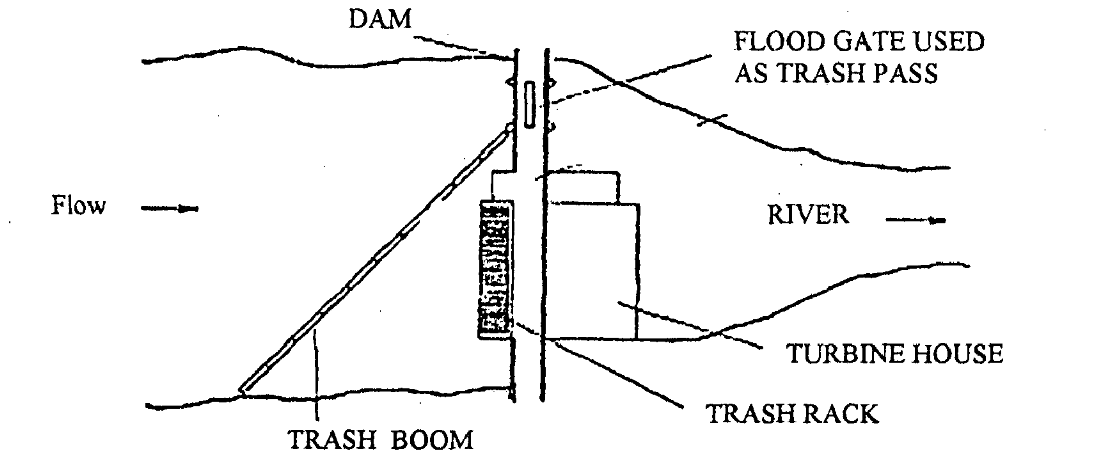


Figure 2 – 2 Trash Boom Protects Trash Rack and Fish Pass From Trash and Floating Ice.

2.1.2 TRASH RACK STRUCTURE

A trash rack is a structure with its water passages protected with steel trash bars to prevent debris from entering the conduit and possibly becoming lodged in the gates or valves or damage the turbine. Many different types of trash rack structures have been developed for this purpose, the choice of type and size depending on the conditions at the site. The structure may be square, rectangular, many sided or circular in shape. The rack may be placed on the sides, and or on top off the structure. Illustrations of various types of trash racks are shown in Fig. 2 – 3 until 2 – 11. The local conditions effecting the choice include the head, the quantity of water to be discharged, the foundation conditions, the ice and trash condition, the frequency and extent of draw down of reservoir and the location and type of gate required.

The shape of trash rack structures may be rectangular or semicircular in shape depending on the size of the conduit, head, velocity of flow and quantity of debris expected. It is desirable that they are constructed as high as possible consistent with economy in order to facilitate cleaning from the top of dam. The height of structure is generally fixed with reference to the fluctuations in the reservoir level and is 1.5 to 3 m above minimum draw down level of the reservoir, which would permit cleaning of racks at least once a year.

Types of Intake and Trash Racks:

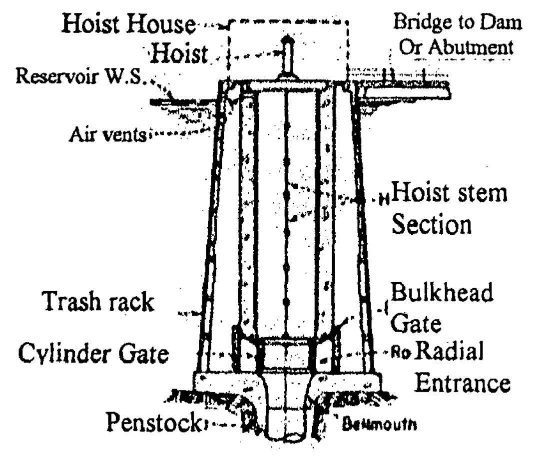


Fig. 2 – 3 Vertical Trash Rack Tower Type Intake

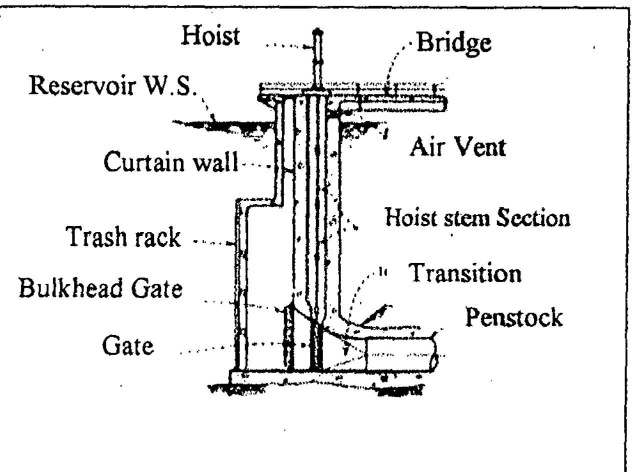


Fig. 2 – 4 Vertical Trash Rack at Tower Type Intake

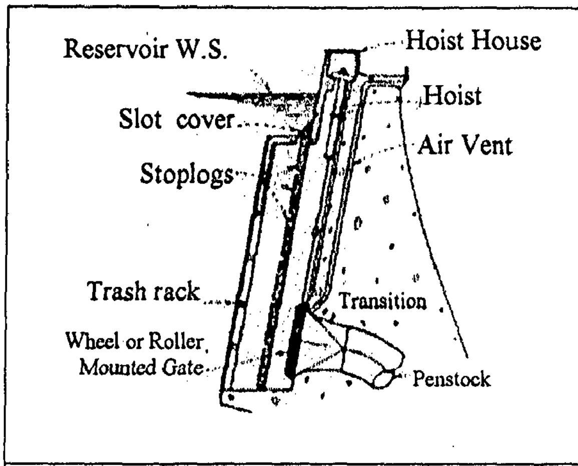


Fig. 2–5 Inclined Trash Rack at Small Slope-Intake on Dam

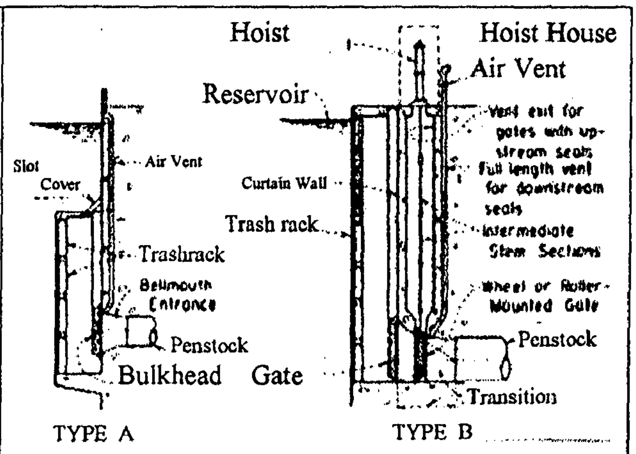


Fig. 2–6 Vertical Trash Rack at Vertical Intake on Dam or Abutment

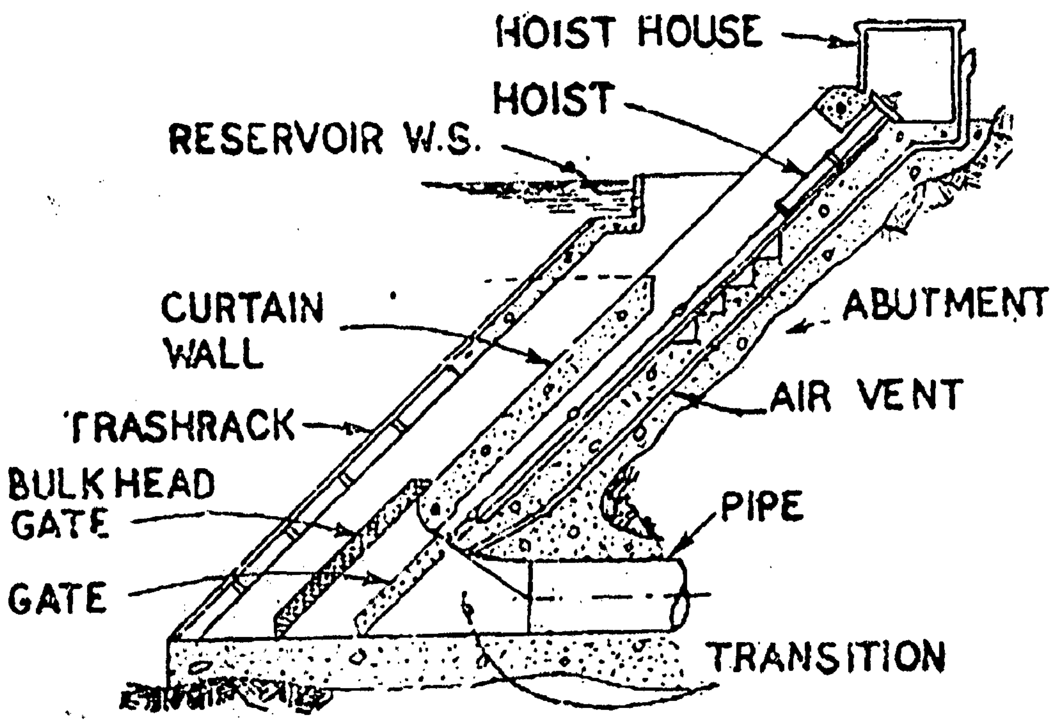


Figure 2 – 7 Inclined Trash Rack at Large Slope Intake on Dam

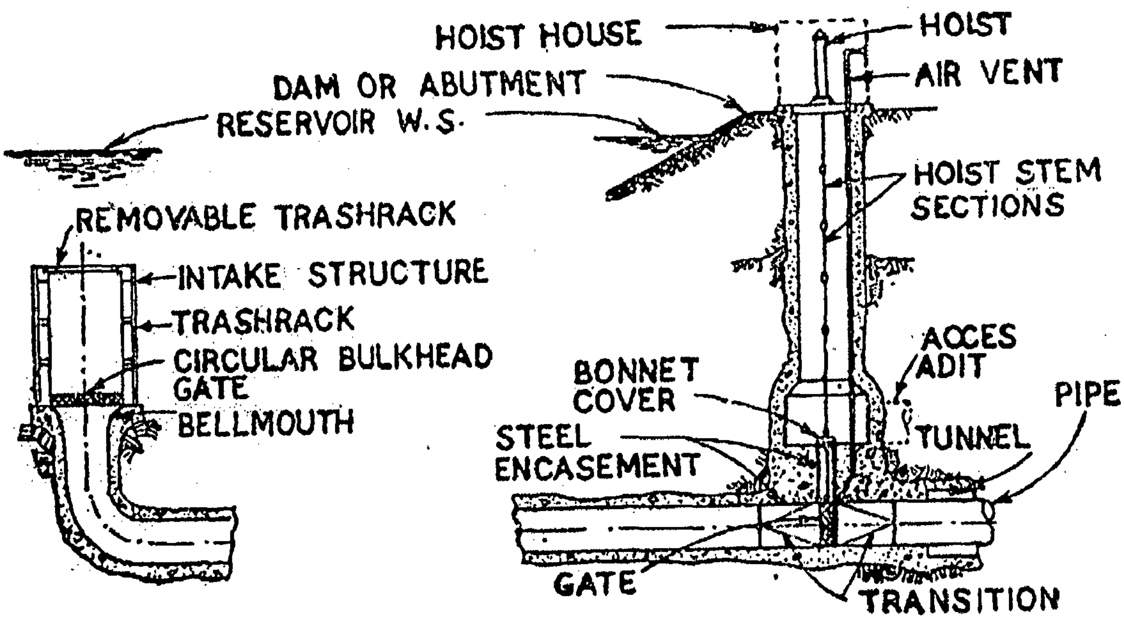


Figure 2 – 8 Removable Trash Rack at Submerged Shaft Intake

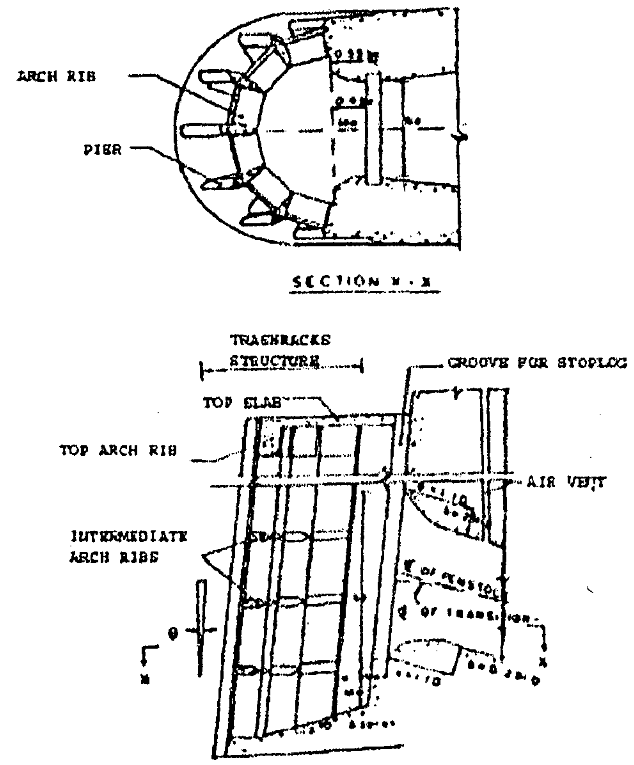
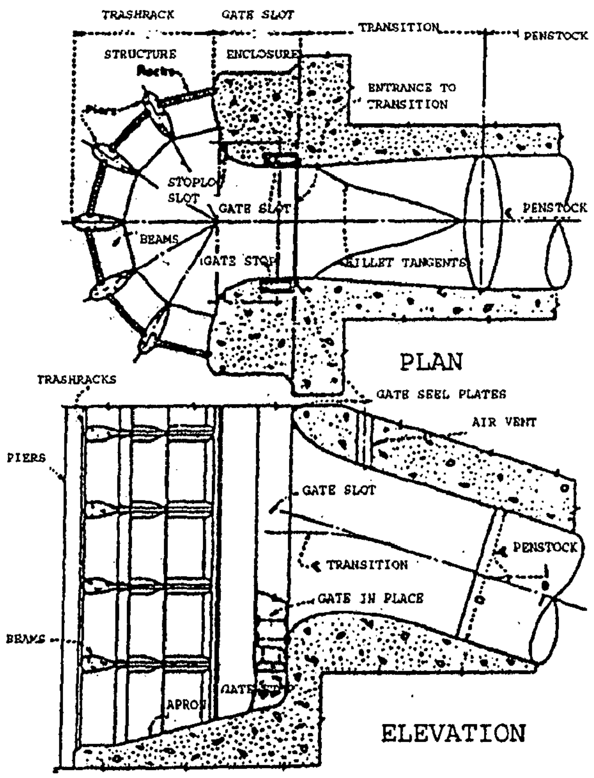


Figure 2 – 9 Inclined Trash Rack at Semicircular Type Intake



Figire 2 – 10 Vertical Trash Rack at Semicircular Type Intake

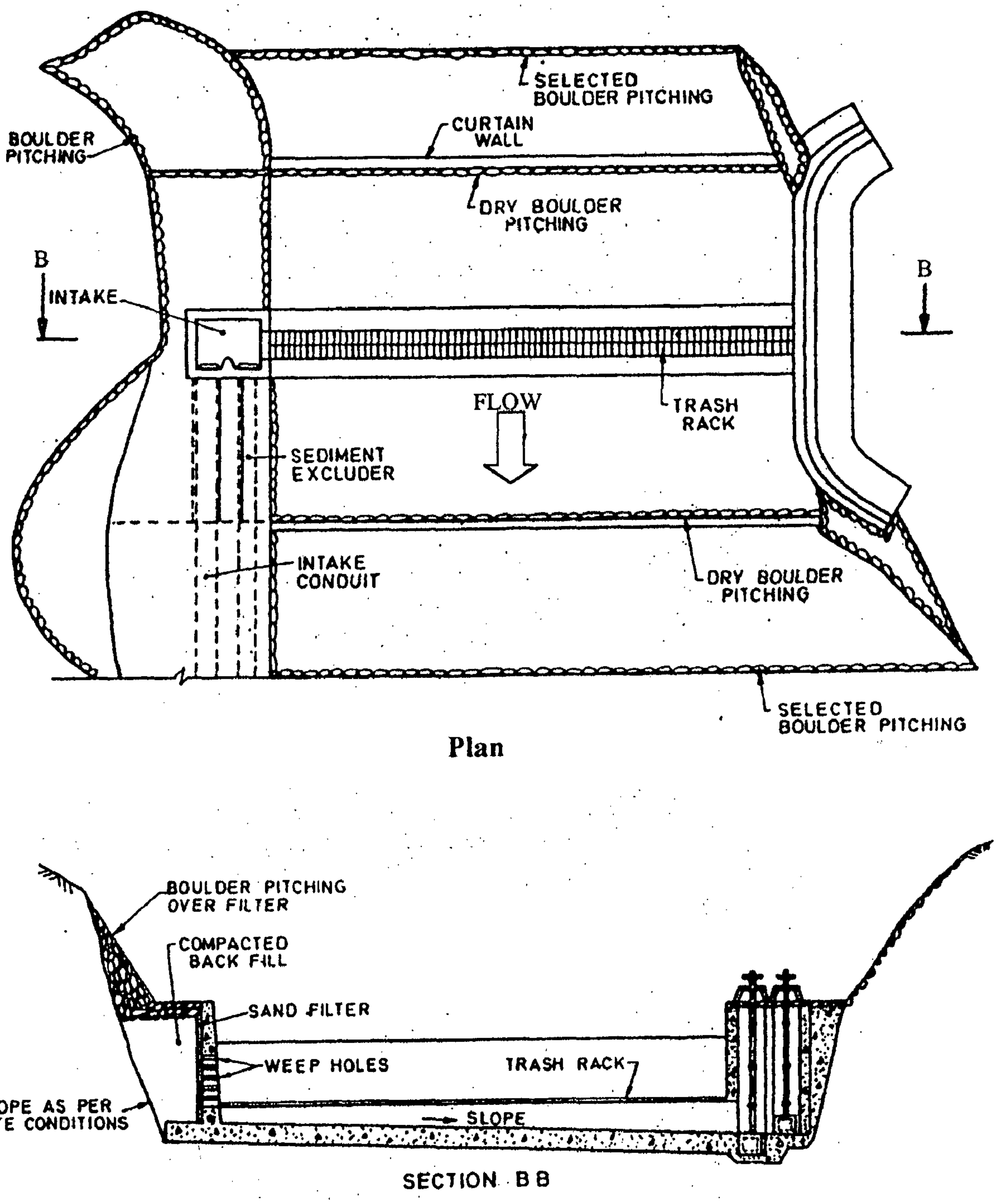


Figure 2 – 11 Horizontal Trash Rack at Drop Type Intake