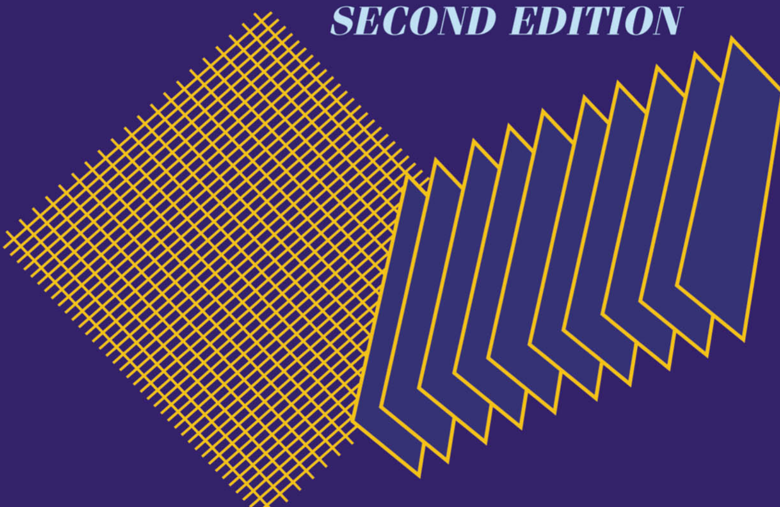
SCREENING EQUIPMENT HANDBOOK

for industrial and municipal water and wastewater treatment

SECOND EDITION



Tom M. Pankratz

CRC PRESS

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For Michael H. Pankratz

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Foreword

WHEN it was first published in 1988, *Screening Equipment Handbook* fulfilled a real need: at last, engineers and operators had a useful reference that identified the large variety of screens available for water and wastewater applications. Screening seemed simpler then, and most screens had rather narrow, clearly defined roles.

Screens could be neatly divided into easy-to-categorize groups. Most in-channel screens had coarse openings. Most fine screens required pumping and resulted in higher than desired headlosses. Some wastewater treatment plants were still designed without any screens at all! The uses and misuses of screens seemed reasonably clear, and *Screening Equipment Handbook* reflected this.

The last six years have brought many changes to the screening equipment industry. The screens that were once precisely and simply categorized are now available in a bewildering variety of designs, sizes, and types. As a result of ingenuity, an increased interest in pollution prevention, the beneficial use of biosolids, and increasingly stringent legislation, the once-clear delineations that included opening size, design, and usage classifications have become blurred.

More consultants are designing municipal wastewater plants in innovative ways, such as substituting fine screens for primary clarifiers. Screens known for their use in pulp and paper mills now regularly appear in wastewater plants attached to vegetable processing facilities.

It's easy to become confused when considering which type of screen might be best for a particular application. There's so much available in the marketplace because the predictable childlike screening market has become an adventurous adolescent. This revision of the Handbook is timely and reflects the many changes that the industry has undergone.

When you have a new project to consider, use this updated book as your reference. Keep your eye firmly on your project's goal and draw on the experience of consulting engineers, respected manufacturers, and their representatives. You'll find there's a screen to help you accomplish your goal. From protecting downstream equipment to capturing by-products for resale, from designing a new grass-roots plant to shoehorning a new screen into an old plant to expand capacity, today's screen market offers the solution you need, and this book will help you identify your options.

ROBIN REDDY
Lake Bluff, Illinois

Preface

THE first edition of *Screening Equipment Handbook* was published in 1988 and was the first comprehensive reference to review the water and wastewater screening equipment industry. The industry has since undergone many changes. Although these changes may not reflect startling new technological advances, they do include improvements in overall screening efficiency, reliability, and economics.

The objective of this second edition of *Screening Equipment Handbook* is to summarize the available screening equipment options and provide a consolidated source of basic design and application information to assist the engineer in selecting a screen best suited for the particular application.

Although every chapter has been completely updated, significant changes have also been made to the chapters dealing with trash rakes and fine screens, and new chapters have been added to introduce screenings handling and comminuters/grinders. Many new photographs and diagrams have been added to illustrate equipment designs and product features, and the number of entries in the Manufacturers' Directory has been almost doubled to include more than 115 up-to-date names and addresses of equipment manufacturers.

The book is divided into chapters that describe specific types of screening or screening-related products. Chapter 1 reviews common screening equipment applications and identifies the types of screens most frequently employed in each. Chapters 2, 3, 4, and 5 review trash rakes, traveling water screens, drum screens, and passive screens, respectively. These screens are most frequently associated with the screening of raw intake water. Bar screens and fine screens are covered in Chapters 6 and 7, which emphasize the use of screens in preliminary and primary wastewater treatment applications. Chapter 8 introduces screenings handling products. Although some of these products have been available for several years, their use continues to increase and represents one of the most significant changes in wastewater screening. Chapter 9 describes comminuters and grinders and their use in the water and wastewater industry, while Chapter 10 reviews microscreen design and application. The appendices include a variety of information that I have found helpful over the years.

After completing the first edition of the book, I continued to find new information that hadn't been included. I frequently wished that publication had been delayed for one or two months, or more. When I mentioned this to my son Chad, he wisely directed me to the following passage from Hemingway's *Death in the Afternoon:*

> I was not able to write anything about the bullfights for five years—and I wish I would have waited for ten. However, if I had waited long enough I probably never would have written anything at all since there is a tendency when you really begin to learn something about a thing not to want to write about it but rather to keep on learning about it always, and at no time, unless you are very egotistical, which of course accounts for many books, will you be able to say: now I know all about this and will write about it. Certainly I do not say that now; every year I know there is more to learn, but I know some things which may be interesting now, and I may be away from bullfights for a long time and I might as well write what I know about them now.

As new information becomes available, there will be contemplation of a new, third edition.

I would like to thank Robin Reddy and Mike Toepfer for reviewing this new edition and providing many helpful suggestions and comments.

In addition to the people and companies who provided illustrative materials for the first edition of this book, I would like to thank the following individuals for their help with this edition: Lars Apelqvist, Tom Baber, R. Baillorgeon, Peter Blake, John Booth, Pascal Bovagnet, Tom Brown, Tim Canfield, Wayne Cassell, Dean Chang, Richard Coniglio, Lee Cook, Larry Crowell, Roger Davidson, Randy Delenikos, Theo de Wolff, J. M. Douglas, Jeff Drake, Mike Drake, B. R. Evans, Erich Fink, Dieter Frankenberger, Rich Gargan, Dennis Geran, P. A. Goeman, Brian Graham, Stacey Grimes, Gary Haggard, H. B. Haffer, Malcolm Haigh, A. Hanson, Dennis Herold, Henry Hunt, P. E. Jackson, William Jungman, Wolfgang Krahn, James Lageman, Ernest Latal, Bill Lauritch, Don Losacco, Gary Leudtke, Vernon Lucy, Gary Mackey, Robert Manwaring, W. David Martin, Werner Marzluf, Jean-Jacques Maurel, G. Meneghetti, Gabriel Meunier, John Mullin, Yusuf Mussalli, A. Neuhold, Delmar Nichols, Finn Nielsen, A. Nilsson, Philip Orrill, Ken Ohyler, Bill Palarz, Becca Pankratz, Joseph Pastore, Alfred Patzig, Tom Quimby, Robin Reddy, L. Reichenau, Stanley Rudzinski, Karl Heinz Rusch, Mr. Schaaf, Kristy Schloss, James Siler, Nico Smits, Rich Sommers, Michael Spring,

C. L. Sprinkle, Judy Stevenson, Fred Tipton, C. H. Van Leeuwen, Mark Watson, Thomas Wingfield, H. Wirth and Jake Zelenietz.

Finally, I would like to thank my wife Julie, and our children Chad, Sarah, Mike, and Katie for their continued support and encouragement.

TOM PANKRATZ
League City, Texas

CHAPTER 1

Screen Applications

THE application of the best screening system for a particular project is somewhat of an art. Although there are many "classic" applications, where one type of screen is obviously better suited than any other, the selection process for many projects is far more complicated.

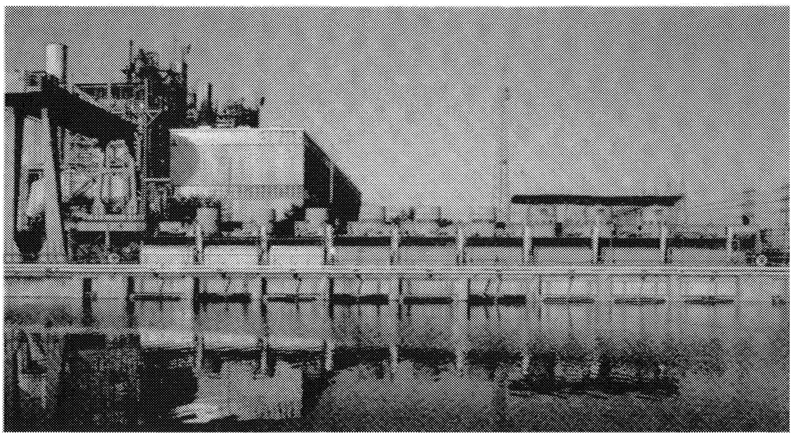
Screen opening size and flow rate are the most important criteria used in the selection of a screening system. Other categories include civil, equipment, and operational costs; plant hydraulics; debris handling requirements; operator qualifications; and availability.

The following categories describe common screening applications within particular industries and the types of screens that they most frequently employ. It is often possible to successfully utilize screens other than the types mentioned below.

ELECTRIC POWER GENERATION

Nuclear and fossil fueled steam electric generating plants require approximately 500 to 1500 gallons of water per minute (32 to 96 L/s) per megawatt of rated capacity. This water is primarily used for cooling purposes in the plant's condensers and must be screened prior to use to prevent clogging of tubes and openings in the surface and jet condensers, as well as interfering with the proper operation of the circulating and condenser pumps.

Many power plants discharge the condenser exhaust directly to a lake, ocean, or river that serves as a heat sink. Most newer power plants recycle their condenser exhaust through cooling towers. Approximately 3% to 5% of the recirculating water must be continually replaced to make up for losses due to evaporation, drift, and blowdown. Such a "closed cycle" cool-



Power plant intake screens, courtesy of Screening Systems International.

ing water system greatly reduces intake water requirements and, consequently, the number of screens.

Traveling water screens and drum screens are used to fulfill the screening requirements at most power plants that use a surface cooling water source. A large power plant that utilizes this "once through" approach in its cooling water system may require as many as forty-eight individual traveling water screens. These screens are usually preceded by a coarse trash rack, equipped with a trash rake mechanism, to remove very large and heavy debris.

Environmental conditions may require screens to be fitted with special features to minimize their adverse affect on fish and other marine life. Many traveling water screen manufacturers offer "fish screen" modifications for these applications.

Some power plants have successfully applied passive screening systems for surface water intakes. These screens virtually eliminate problems associated with debris handling/removal and may make compliance with environmental regulations easier.

Hydroelectric power stations in the northwestern United States may use traveling water screens to screen the pumped recirculating water on a fish ladder system. This is a relatively low flow application compared to the other previously described power plant screen uses and usually requires two or three screens.

Static screens and manually cleaned bar screens have been used successfully to dewater spray water produced by traveling water screens and drum screens.

WOOD PRODUCTS INDUSTRY

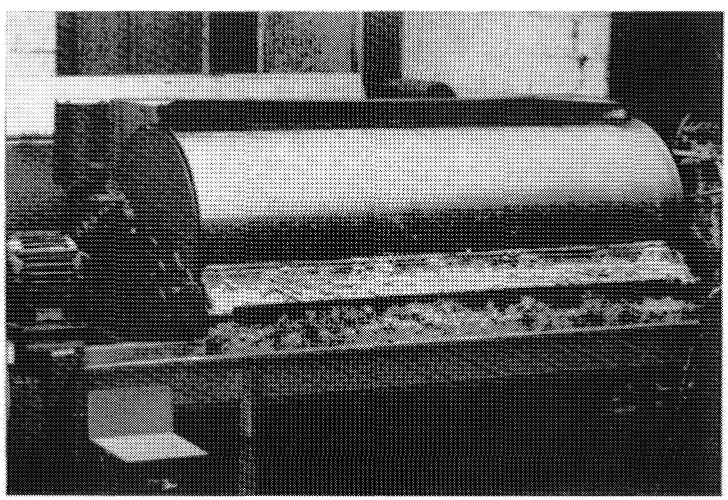
Pulp and paper plants are intensive users of raw water, requiring up to 20,000 gallons (76 m^3) of water per ton of product. Many pulp, paper, and saw mills generate their own electricity and use traveling water screens to screen raw condenser feedwater and process water prior to its use.

Most mills process the logs used as raw materials for their product. The logs are conveyed from the woodyard to large debarking drums via a flume. Prior to being recycled, the flume water passes through a grit chamber followed by one or more traveling water screens, static screens, or rotary fine screens to remove bark, leaves, and twigs that have fallen off or been removed during handling.

Some paper plants and kraft mills utilize static screens and rotary fine screens in their waste treatment process, prior to clarification, to remove and/or recover floating and suspended fibers and other particles that might hinder sedimentation. Other fine screen applications in paper and pulp mills include broke thickening, save-all, and whitewater screening.

MISCELLANEOUS MANUFACTURING AND PROCESSING

Food processing, steel mills, petro-chemical plants, refineries, textile, and other large manufacturing plants also require the use of mechanical



Poultry processing, courtesy of Hycor Corp.

screening equipment. Requirements for many of these applications are very site-specific.

Fine screens are also commonly used for solids' separation or product recovery. Selection of the proper type of fine screening equipment is highly dependent on the volume and consistency of the solids to be screened.

Traveling water screens are usually used to screen fire water, condenser and process cooling water, boiler feedwater, potable water, and process water. For lower flow application, mechanically cleaned bar screens have also been used successfully.

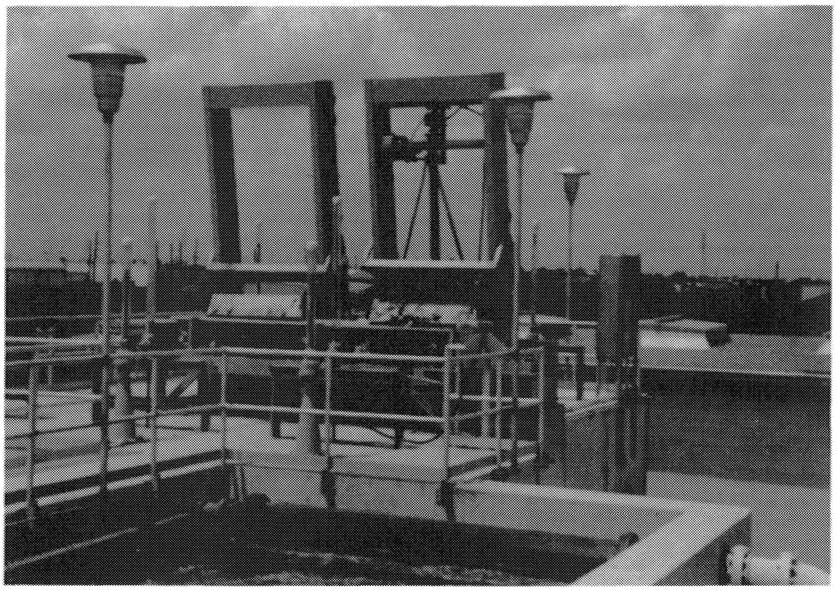
IRRIGATION PROJECTS

Irrigation and other open-channel water distribution projects in the western and southwestern United States may use traveling water screens, belt screens, or bar screens to protect pumping equipment at remote pump stations.

WATER TREATMENT PLANTS

Large surface water treatment plants and desalination plants may employ traveling water screens, drum screens, bar screens, or passive screens

Irrigation pump station, courtesy of FPI, Inc.



Wastewater treatment plant, courtesy of Infilco Degremont.

to screen raw intake water as the first step in the treatment process. Inadequate screening may result in damage to downstream equipment, may increase chemical requirements, and may hinder the treatment process.

WASTEWATER TREATMENT PLANTS

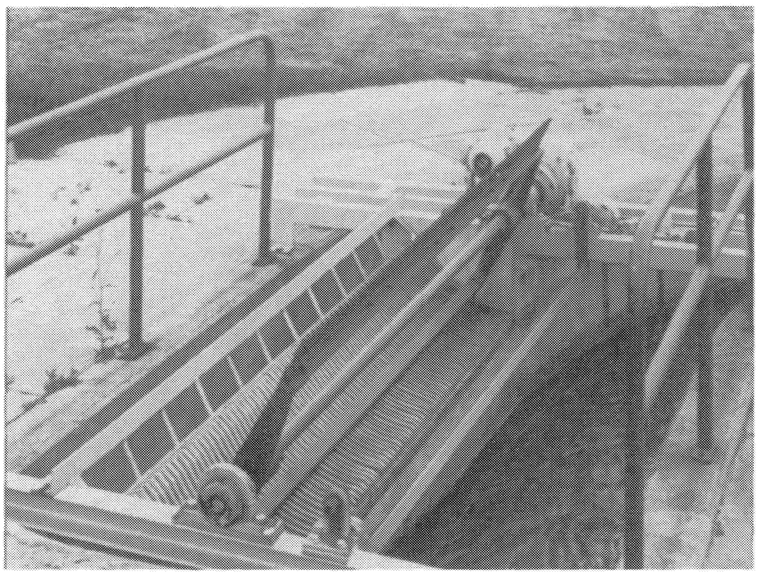
One or more bar screen and/or fine screen can be found at virtually every wastewater treatment plant in the world. The type of screens used ranges from manually cleaned, coarse bar screens to fully automated microscreens.

Screens may be used in preliminary, primary, and tertiary treatment processes in a wastewater treatment plant. The use of fine screens for the screening of sludge, grease, scum, and solids produced in other treatment processes has increased significantly since the mid-1980s.

Application examples and suggestions are further discussed in the Bar Screen, Fine Screen, Drum Screen, and Microscreen chapters of this book.

COMBINED SEWER OVERFLOW

The use of screens in Combined Sewer Overflows (CSO) applications are increasing since publication of the U. S. EPA's draft policy requiring



Stormwater overflow, courtesy of Longwood Engineering.

CSO's to install nine minimum controls, including the control of solid and floatable materials in CSO discharges. One of the most effective methods of meeting this requirement is to install screening equipment at the CSO discharge. Bar screens, fine screens, drum screens, and traveling water screens have all been used successfully in CSO systems.

Trash Rakes

TRASH rakes are heavy duty raking devices that are used to remove large or rough debris retained on a trash rack. They protect pumping equipment at electric generating plants, desalination plants, pump stations, and flood control projects and may be used as a preliminary screening device to protect finer screens such as traveling water screens or drum screens.

A trash rake consists of one or more stationary trash rakes and a screen raking mechanism. Bar spacings on the trash rack usually range from 1-1/2″ to 4″ (38 to 100 mm). Most racks are constructed of carbon steel bars, but at least one manufacturer offers trash racks constructed entirely of high density polyethylene polymers. This rack weighs up to 75% less than its carbon steel counterpart, and is less prone to problems resulting from frazil ice, marine growths, and corrosion.

Trash racks can be equipped with sensors to detect the presence of scuba divers or boats in the intake area.

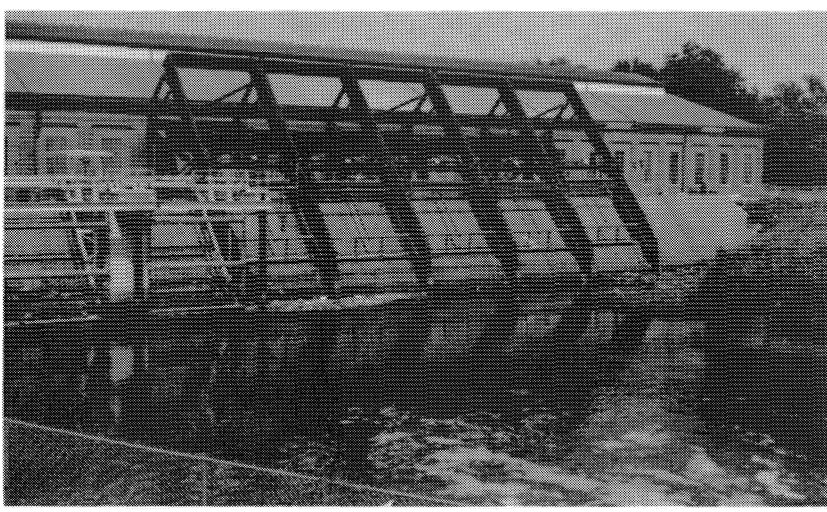
There are a variety of raking mechanisms available for use in a variety of intake configurations, including installation on vertical building and dam walls. Rakes may be mounted on fixed structures designed to clean a single trash rack, suspended from an overhead gantry, or wheel-mounted to traverse the entire width of an intake structure and clean individual sections of a very wide trash rack.

Trash rakes have been designed with effective rake widths of up to 20 ft (6 m). The largest cleaning depth reported is 350 ft (164 m).

Some mechanically cleaned bar screens, including the reciprocating rake and catenary types, have been adapted for use in trash rake applications.

Because of the large variations in bar spacings, debris loading, and the application of trash rakes, there is no established relationship for the quantity of screenings removed per unit volume of flow.

Trash rake installation, courtesy of Bieri Hydraulik.



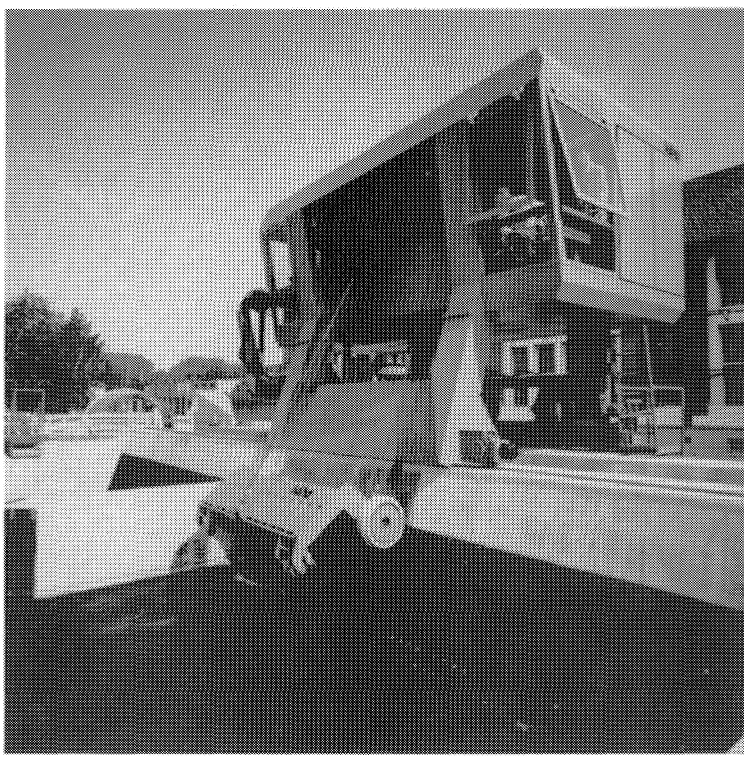
Trash screen installation, courtesy of Infilco Degremont.

CABLE OPERATED TRASH RAKES

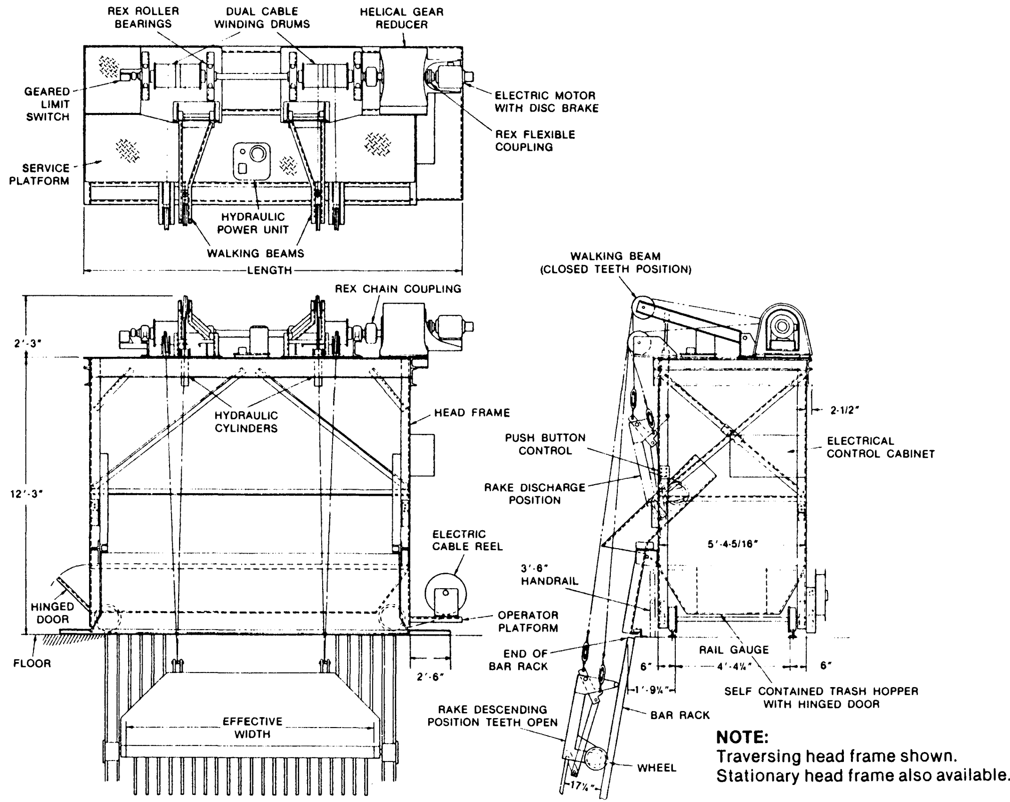
This trash rake design uses a single, toothed rake that is raised and lowered by means of one or more sets of stainless steel cables to clean a stationary trash rack. The rack is lowered down the upstream face of the trash rack with the teeth in the open, disengaged position. As the rake reaches the channel bottom, the teeth are rotated to their closed position, meshing with the stationary bars. The rake is then lifted up the face of the trash rake, collecting accumulated debris. As the rake reaches the discharge position above the operating deck elevation, the teeth are opened, discharging debris into a trough or hopper.

RAKE HOIST

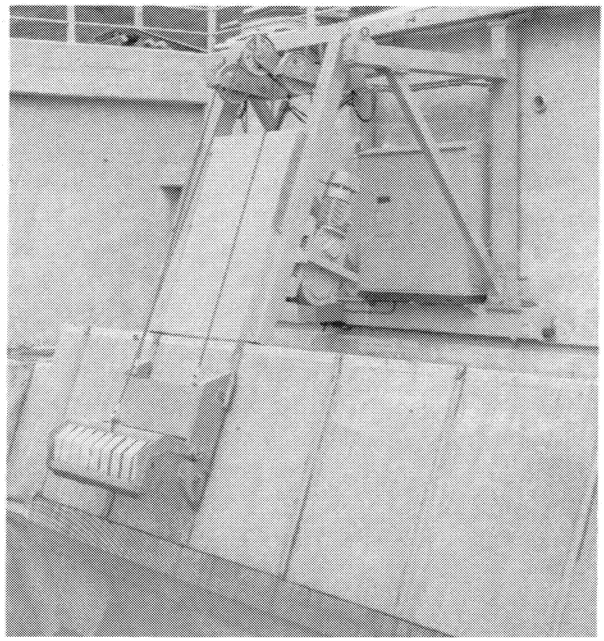
The upper ends of the 3/8″ (9 mm) minimum diameter rake cables are fixed to a shaft-mounted hoist drum. The drum's line shaft operates in self-



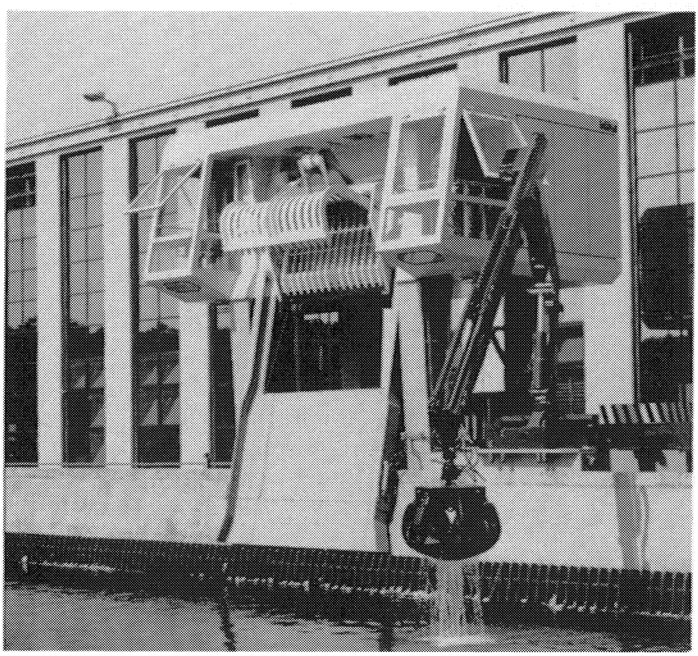
Cable operated trash rake, courtesy of Hans Kunz GesmbH.



Cable operated trash rake arrangement, courtesy of Envirex, Inc.



Wall-mounted trash rake, courtesy of Bieri Hydraulik.



Trash rake with grab crane, courtesy of Hans Kunz GesmbH.

aligning roller bearings and is directly coupled to a drive unit furnished with a motor mounted brake. Rotation of the hoist drum changes the effective length of the cables and results in the raising or lowering of the rake. The excess cable that accumulates during the rake's ascent is stored on the periphery of the grooved hoist drum. Limit switches automatically stop the rake at the top and bottom of its travel. Hoist speeds may range from 15 to 40 ft (4.5 to 12 m) per minute. Two speed hoist drives (slow descent, fast ascent) may be used for deep trash rake installations to reduce rake cycle times.

Standard duty trash rakes are furnished with a single hoist drum and one set of cables to lift objects up to 17″ (430 mm) in diameter, with hoist capacities to 2000 lb (900 kg). Heavy duty units may be capable of lifting objects up to 24″ (600 mm) in diameter and are furnished with dual hoist drums and two sets of cables, with hoist capacities to 4600 lb (2000 kg). The hoist mechanism should be equipped with a slack cable safety switch and an over-travel switch. Hoist drive motors typically range from 1 to 7.5 horsepower (0.75 to 5.6 kW).

RAKE TOOTH OPERATION

The cleaning cycle begins when the rake is lowered to the bottom of the channel and the rake teeth are rotated to the closed, engaged position. Most designs allow the rake teeth to penetrate the bar rack a minimum of 1/2″ (13 mm).

Tooth opening and closing are accomplished by changing the effective cable length. This may be done by controlling the slippage between a fixed and free segment of the hoist drums. This system requires that the inside drum, or drum segment, be keyed to the drum shaft. The other drum is free for limited rotation controlled by the fixed drum. The free drums are equipped with band brakes to allow for the opening of the rake.

An alternative arrangement for operating the rake teeth uses a walking beam assembly. This system requires a small hydraulic power unit to operate a hydraulic cylinder that is used to raise and lower a walking beam assembly, changing the effective length of the tooth control cables. Hydraulic relief valves automatically open the rake teeth if an overload condition occurs.

GUIDED RAKE

Each end of the rake assembly may be equipped with wheels or sliding blocks to operate in guide channels embedded in the walls of the concrete channel. The guided rake design is recommended for vertical trash racks or trash racks inclined less than ten degrees from vertical.

NONGUIDED RAKE

The nonguided rake design allows the rake to rise over obstructions on the trash rake and is preferred for most trash rake installations. This design requires the rake assembly to be equipped with flanged wheels, each wide enough to ride on two bars. Nonguided rake designs are recommended to be used with trash rack inclinations of ten degrees or more.

TRAVERSING MECHANISM

Trash rakes can be mounted on a self-propelled hoist frame capable of traversing the width of an entire intake. This allows the trash rake to be positioned to clean a specific portion of a wide trash rack.

A drive unit can propel the screen hoist frame at a speed of approximately 25 ft (7.6 m) per minute on flanged wheels riding on tee-rails. Tie-down clamping brackets are used to engage the downstream rail and prevent the unit from tipping as large debris loads are lifted. The hoist frame is usually equipped with an operator's platform or cab and a push-button control station from which the unit is operated. A pendant control station may also be furnished.

The rake's transition from the trash rack to its discharge position on the hoist frame is accomplished through the use of a deadplate constructed as an integral part of the hoist framework. For most installations, the deadplate should be designed to operate over a 3′-6″ (1 m) high handrail. A spring-loaded electric cable reel with sufficient cable to span the intake structure must be provided to store the electric power cable.

DEBRIS TROUGH OR HOPPER

Debris collected by the rake can be discharged into a trough, debris hopper, or conveyor located on the downstream side of the trash rack. Debris hoppers are often fabricated as an integral part of the hoist frame and should be furnished with a hinged bottom or side door for debris clean-out. The debris hopper may be wheel- or rail-mounted and designed so that it can be removed from the frame entirely. Commercial "dumpsters" may also be utilized as trash rake hoppers.

Some trash rake machines are equipped with a hydraulic grab crane to unload debris from the unit's hopper. The grab crane may also be used to remove large floating debris in front of the trash rack.

CHAIN-OPERATED TRASH RAKE

Chain-operated trash rakes use toothed rakes or debris lifters mounted