



UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Suite 322
315 South Allen Street
State College, PA 16801

'82 DEC 13 AM 11:17

ATLANTA
: GEN

December 7, 1982

Mr. Lawrence Brenner
Administrative Judge
Atomic Safety & Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Judge Brenner:

I am enclosing several pages from a recent publication "Design of Water Intake Structures for Fish Protection". I have marked the sections referring to the 2:1 velocity difference across the intake and the potential for bio-fouling even in fresh water.

This is in support of testimony I gave November 22, 1982, on behalf of Del-Aware Unlimited, Inc., Philadelphia Electric Company (Limerick Generating Station Units 1 and 2), Docket No. 50-352-OL and 50-353-OL. Even if this cannot be submitted as evidence in the hearings, I felt it may help you better understand the intake issue.

Sincerely,

Richard W. McCoy

Richard W. McCoy
Fish & Wildlife Biologist

Enclosures

8212160316 821214
PDR ADOCK 05000352
G PDR

DEC 13 1982

*Design Of
Water
Intake
Structures
For Fish Protection*

Prepared by the
Task Committee on Fish-Handling Capability
of Intake Structures
of the Committee on Hydraulic Structures
of the Hydraulics Division of the
American Society of Civil Engineers



Published by the
American Society of Civil Engineers
345 East 47th Street
New York, New York 10017

Disadvantages of The Radial Well Intake System

1. The radial well is only suitable where there is a porous aquifer with the capacity to provide the quantity of water required. Unfortunately, intake sites that can be suitably developed are limited. Vertical test wells must be drilled and tested to determine the characteristics of the aquifer and the magnitude of the required collector system. Such a testing program may take from two to four months.
2. The individual caisson units are limited to about 25,000 gal/min (100 m³/min) but probably much less in most usable aquifers. To handle larger water requirements, widely spaced multiple units are required and all must be connected to a common transmission pipe to the plant.

Recommendations for Preliminary Design

Listed below are typical characteristics for a radial well intake. This information will be of value in determining the order of magnitude of such an intake for a given site.

1. The usual capacity of individual collector units is in the 1,000 to 10,000 gal/min (4 to 40 m³/min) range, but could go as high as about 25,000 gal/min (100 m³/min) in a very favorable aquifer. Many radial wells have been placed in relatively thin aquifers with limited capacity.
2. Collector caisson spacing for multiple units is typically 1,500 ft (458 m). An array of collectors may thus spread over a large area.
3. The diameter of the caisson depends on the space requirements for the pumps and on the clearance needed for lateral screen jacking operations. Smallest readily available forms are for a 13 ft (3.96 m) inside diameter concrete caisson. A 16 ft (4.88 m) ID is a typical size.
4. Caissons placed to depths of up to 200 ft (61 m) from the surface are feasible. Water may be drawn from two or more separate aquifers if necessary, with radial screens jacked into the aquifers at different elevations from inside the caisson.
5. The typical diameter of radial collector screens is 8 to 16 in. (20.3 to 40.6 cm) but sizes to 48 in. (122 cm) could be considered for jacking into a very high yield aquifer.

6. The maximum jacking length of the radial screens is in the order of 450 ft (137 m) for any diameter. The usual length is between 150 ft and 300 ft (45.7 and 91.4 m). Diameter does not appreciably influence jacking length.
7. Inflow velocity through screen perforations ranges from 1 to 2 fpm (0.30 to 0.61 m/min). The lower velocities are suitable for fine sand aquifers or corrosive waters.
8. Net open area of the perforated screen ranges from 18 to 22 percent with the larger percentage generally applying to larger screens. Required beam strength is a criteria. Perforation sizes range from .080 to 0.375 in. (2.0 to 9.5 mm) wide depending on the geological characteristics of the aquifer.
9. Assuming typical values of 18 percent open area and an inflow velocity of 1 fpm (0.30 m/min), the total length of laterals can be determined from the following formula:

$$L \text{ (ft)} = \frac{2.837 \times \text{gal/min}}{\text{Screen Diameter (Inches)}}$$

$$L \text{ (m)} = \frac{5.805 \times \text{m}^3/\text{min}}{\text{Screen Diameter (meters)}}$$

10. Low carbon steel is the usual collector screen material. In relatively noncorrosive waters, a minimum life of 30 years can be expected. In corrosive waters and where longer life is desired, stainless steel or other corrosion resistant material can be used.

Subsurface borings must be made to develop site specific design information for any but a very preliminary design. If the borings indicate one or more potential aquifers, then vertical test wells for test pumping and for ground water level observations must be drilled and a test program undertaken in the same general manner required for proving out a vertical well installation.

CYLINDRICAL SMALL-OPENING PIPE INTAKE

General - The presently recommended small-opening pipe intake for the reduction of entrainment is similar to the cylindrical pipe concept discussed in Chapter IV, with the following two significant differences.

1. The openings are much smaller, say 0.02 to 0.08 in. (0.5 to 2 mm) wide, compared with 1/4 in., 3/8 in., or 1/2 in. (6.4 mm, 9.5 mm, or 12.7 mm) normally used for cylindrical pipe intakes.
2. Due to the very small openings, periodic clogging by impinged material or biological growth must be expected and the screen system, therefore, must be designed so that operators have easy access to the screen unit for cleaning. Unlike the large-opening perforated pipe inlet, it cannot be placed in deep water or far from shore where access would be difficult.

Although the openings in the pipe can be punched perforations (holes or slots) or profile wire, the profile wire is the favored screening medium and its use will be assumed in the discussion. Unlike most of the intake screen designs recommended in this text, the concept of the small-opening profile-wire screen is new and relatively untested. There are no installations for power plant service presently in existence. Many field tests are presently underway and have clearly indicated at least some measure of entrainment reduction. The committee accordingly recommends consideration of small-opening profile wire screen in light of the scarcity of alternative means for reducing entrainment.

Biological Considerations - Biological research on cylindrical, profile-wire screens indicates that they could be relatively effective in preventing the entrainment of fish eggs and most larvae at power plants provided that the screen slot size is small (approximately 0.02 to 0.04 in. (0.5 to 1.0 mm), that the through-slot velocity is low approximately 0.5 fps (0.15 m/sec), and that a relatively high velocity (1.0 fps (0.30 m/sec) or greater) cross-flow exists to carry organisms around and away from the screen (9).

In laboratory studies, Hanson et al. (10) found that entrainment of fish eggs (striped bass), ranging in diameter from 0.07 to 0.13 in. (1.8 to 3.2 mm), could be eliminated with a profile-wire screen incorporating 0.02 in. (0.5 mm) slot openings. However, striped bass larvae, 4 to 20 days old, measuring 0.2 to 0.37 in. (5.2 to 9.2 mm), were generally entrained through a 0.04 in. (1 mm) slot at a level exceeding 75 percent within 1 minute of release in the test flume. Larval tests were conducted in a static mode with no crossflow passing the screen. It was concluded that, since positive rheotaxis was observed among these early larvae, a crossflow would act to reduce entrainment to some extent. An ambient current could therefore help in preventing larval entrainment.

However, it could be expected that some of the early larvae of many species would be susceptible to entrainment. Further, with 0.04 in. (1.0 mm) slot openings, eggs or some species would also be subject to entrainment.

Field studies (11) have been conducted with profile-wire screens to determine their potential for minimizing entrainment at a proposed power plant to be located on the St. Johns River in Florida. Intake screens incorporating both 0.04 to 0.08 in. (1 and 2 mm) mesh were tested in situ via a simulated intake structure; an unscreened intake pipe was utilized as a control condition. The results of these studies indicated that entrainment of fish larvae was reduced by the profile-wire screens by more than 60 percent as compared to the unscreened intake pipe. Only small differences in entrainment were noted between the 0.04 and 0.08 in. (1 and 2-mm) mesh screens.

The only field study of profile-wire screens for possible application to a once through cooling water system were conducted at the J. H. Campbell Plant on Lake Michigan (12). The study design was similar to that described above except that mesh sizes of 0.08 and 0.37 in. (2 and 9.5 mm) were tested in comparison to an open intake pipe. In this case, it was also concluded, based on plankton net tow data, that a profile-wire screen intake would reduce entrainment. However, no significant differences in entrainment were detected between either mesh size or the open pipe. Therefore, the mechanism by which the apparent reduction in entrainment into the screens and pipe occurred is unclear. Nevertheless, a profile-wire screen intake has been installed and is operating at the Campbell Plant, supplying water on a once-through basis from a submerged location over 3500 ft (1068 m) offshore. Slot width is 0.37 in. (9.5 mm), not the small size being considered in this section. Operational data are not available at this writing.

Due to the small slot size, 0.02 to 0.04 in. (0.5 to 1.0 mm), and slot velocity, 0.5 fps (0.15 m/sec), entrapment or impingement of juvenile and adult fishes would not be expected to occur. Therefore, the profile-wire screen alternative appears to offer a potentially effective means of reducing fish losses.

Engineering Considerations - A conceptual intake design specifically adapted to the small-opening screen is shown in Fig. V-4. The essential elements are as follows:

1. Multiple screen units are used.
2. The screen units are small enough in size and weight to permit convenient handling.
3. The units are mounted in such a manner that they can be periodically removed from the water and manually cleaned, inside and outside. It is expected that normal operation will require a regular schedule of removal to clean off biological growth that cannot be removed by backwashing.
4. Piping downstream of the screens is designed so that individual screen units can be isolated, backwashed, or removed without affecting the operation of remaining units.

The following general factors must be considered when designing this type of screen:

1. Potential for clogging, especially from biological growth. Tests to date indicate significant, but manageable, biological growth in salt water and a lesser growth in fresh water. The performance of the screen is thus site related. There is a significant difference in the degree of biological fouling on various materials available for fabricating the screens. Stainless steel is the standard material used for profile wire screens. Some alternative materials that are more effective in discouraging biological growth and can be successfully fabricated using standard manufacturing procedures include 70-30 copper nickel, 90-10 copper nickel, Carpenter 20 (20% chromium stainless steel), Ampco 8 (Aluminum bronze) and monel (13)(14). Periodic painting with antifouling paints has also reduced biological growth in test installations.
2. Size of the opening required to achieve the desired results at a given site. Consider the size of the organism to be prevented from entering and use the largest opening that will produce the desired result.
3. Velocity of inflow. An average slot velocity of inflow of about 0.5 fps (0.15 m/sec) has been a common figure used to date. However, greater or less velocities may be better suited to a particular situation.

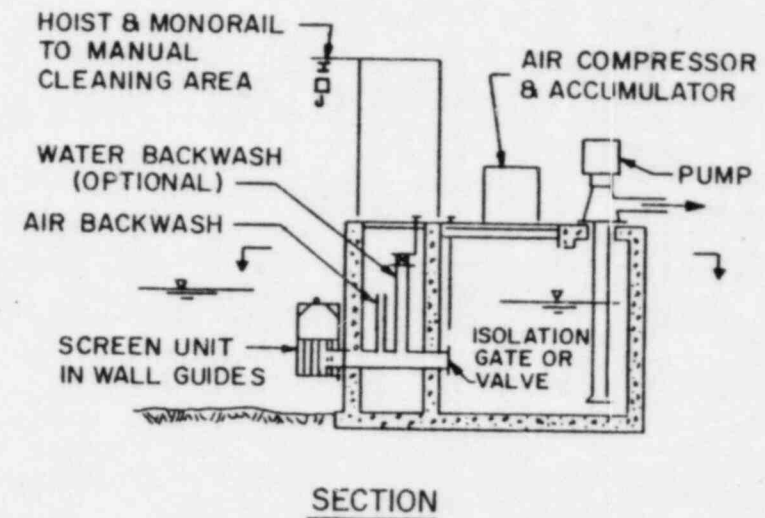
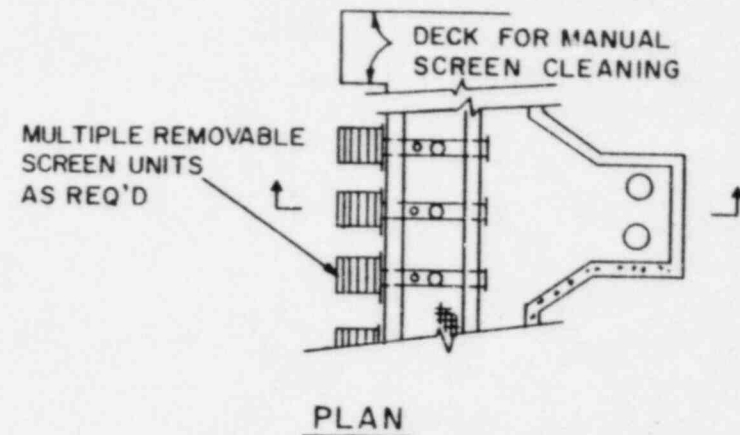


Figure V-4 CYLINDRICAL SCREEN INTAKE WITH MULTIPLE MANUALLY CLEANABLE UNITS

Source: Richards (Ref. 41)

4. Geometry of the screen to give optimum performance. The simple small-opening cylindrical screen will have the same poor velocity distribution characteristics as a similar larger opening screen discussed in SECTION IV. The length should not exceed the diameter, and an internal projecting pipe or other internal velocity distributor should be used.
5. Possible adverse influence of ice formation or ice collection on the screen surface.
6. Influence of adjacent screen units on one another, during both normal flow and backwashing. Performance will be influenced by the direction and velocity of ambient currents at the point of water intake.
7. Method of backwashing. As stated in SECTION IV for larger opening perforated pipe screens, air blast backwash has been found to be effective. Air can be introduced into the lead-in pipe upstream of the screen unit, Fig. V-5A, or can be discharged from a multiported header inside the screen unit itself, Fig. V-5B. Testing has shown that the latter scheme is more complex but more effective. If the air enters the lead-in pipe, then the screen unit must be isolated by valve during backwashing. This is not necessary for the multiported air header, Fig. V-5B. An air blast volume of 2 to 3 times the screen unit volume, at a pressure of 100 psi (690 kPa), has been found to be effective in installed units studied to date. It is desirable to remove all water from the air backwash piping upstream of the screen unit just prior to injection of the compressed air. This can be done by first bleeding air into the piping to displace the water.

Advantages of the Small-Opening Cylindrical Pipe Intake

1. The small screen opening can be designed to keep many entrained organisms from entering the water system.
2. There is no confined channel leading to the screens, thus eliminating a possible area for entrapment of swimming organisms.

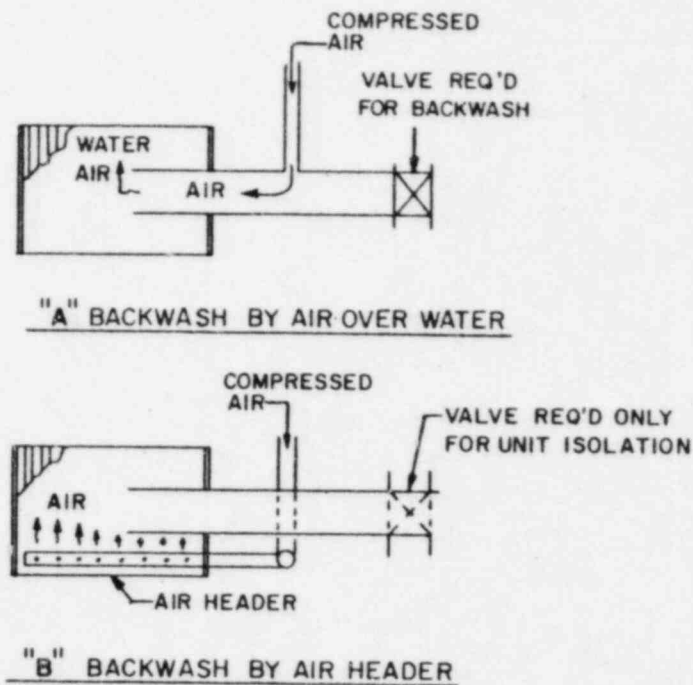


Figure V-5 TYPICAL AIR BACKWASHING METHODS

Source: Richards (Ref. 41)

3. The approach velocity to the screen face falls off very rapidly and is negligible a few inches from the screen, as discussed in SECTION IV for perforated pipe intakes and indicated in Fig. IV-32. The tendency for swimming organisms to impinge is thus low.
4. Impinged organisms can be removed by backwash without these organisms leaving the water, unlike the traveling screen which is cleaned above the water surface.
5. Trash bars, trash rakes, and traveling screens are not required. This is an advantage from economic, operational, and maintenance points of view. The manual cleaning of the cylindrical screen units requires less skilled personnel than the maintenance of traveling screens.

Disadvantages of the Small-Opening Cylindrical Pipe Intake

1. The site conditions must be such that relatively deep water is close to shore so that a structure similar to Fig. V-4 can be used. Unlike the large opening perforated pipe intake discussed in Section IV, it cannot be placed at a remote offshore location inaccessible for periodic removal and cleaning.
2. Backwash piping and valving is relatively complex for a large array of screen units. Also, the screen and guide materials tend to be more costly than for standard screens. It is possible that these factors will negate much of the economic advantage of the elimination of trash bars and traveling screens.
3. Intakes proposed to date for water quantities up to say 50,000 gal/min ($200 \text{ m}^3/\text{min}$) require a large number of relatively small screen units resulting in a total structure size greater than that utilizing conventional screens. The intake can undoubtedly be designed for substantially larger quantities of water, but the screen units must be larger than any proposed to date and handling and cleaning will be more difficult.
4. The small-opening screens have not to date been proven suitable for all water qualities. Until more substantial test and operational data become available, preinstallation testing is recommended for each site. This will include biological testing, corrosion testing, and the testing of the screen system as a whole, with regard to spacing of screen units to avoid interference under specific site waterway flow conditions.

Recommendations for Preliminary Design of a Small-Opening Cylindrical Pipe Intake

For preliminary design purposes, the following parameters may be used in addition to those general factors enumerated above:

- a. Screen unit diameters for the removable type of screen being discussed here have to date been in the range of 24 to 48 in. (61.0 to 121.9 cm). Commercial automatic winding of profile-wire screen is presently limited to 36 in. (91.4 cm) above which manual fabrication is required. However, the overall cost of the screen unit vs. flow capacity is not greatly increased by the manual fabrication. Handling weight for convenient removal and washdown will be a factor in size selection.
- b. Limit the length of the screen unit to the diameter of the screen or less and extend the outflow pipe into the interior of the screen about 40 percent of the screen length. This modification will result in a reasonably uniform inflow and will permit convenient handling for the specific type of wall-mounted screen to which this discussion applies. Tests to date have shown that the maximum inflow velocity for this design will be about 125 percent of the average.
- c. To size the pipe leading from the screen unit into the pump chamber, assume a maximum outlet velocity of about 5 fps (1.5 m/sec). Tests to date indicate that the flow into the screen will be uniform when this design procedure is used.
- d. The end plate of the screen unit may be either closed with a solid plate or with additional screen material. There is evidence that air blast backwashing is more effective if the end plate is solid.
- e. Physically locate the screens to allow for at least 24 in. (61.0 cm) of head loss from the inlet system to the pump chamber, including losses through the screen itself, the piping and the valving. This will allow for head loss buildup between cleaning operations.
- f. Determine the total area of the screen by assuming an opening width based on the biological requirements and assuming a wire size from the manufacturer's catalogue. For example, a typical

profile wire size is 0.069 in. (1.75 mm) wide on the front face. For this wire typical percent openings would be as follows:

TABLE V-2

OPEN AREA VERSUS WIDTH OF OPENING FOR 0.069 INCH PROFILE WIRE

Width of Opening	Percent of Open Area
0.02 in. (0.5 mm)	22%
0.04 in. (1.0 mm)	36
0.06 in. (1.5 mm)	46
0.08 in. (2.0 mm)	53

- g. Provide at least one more screen unit than called for based on total area required. This will permit maintaining the desired flow area with one unit out of service for backwashing or manual cleaning. Provide suitable valving and piping to permit isolation of each unit separately for backwashing or removal.
- h. Provide an air backwash system.
- i. Space the screens at least twice the diameter of the screen apart to avoid mutual interference of the flow fields approaching the screens.

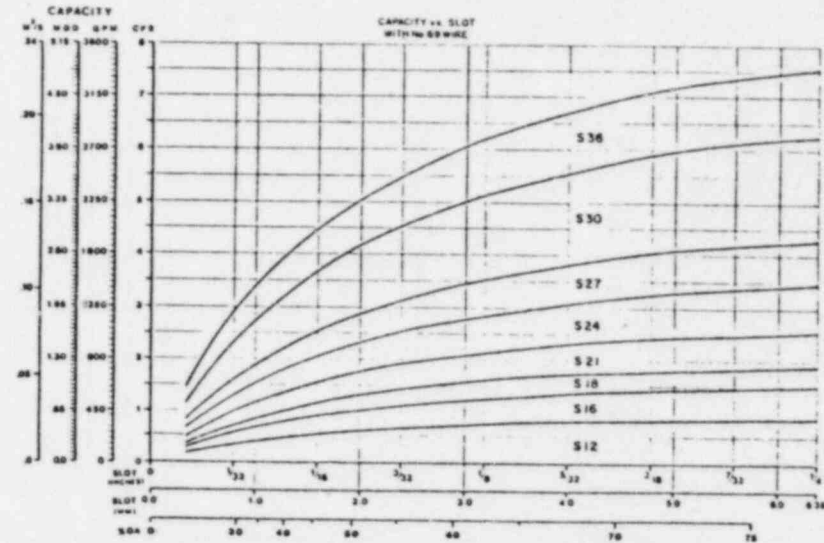
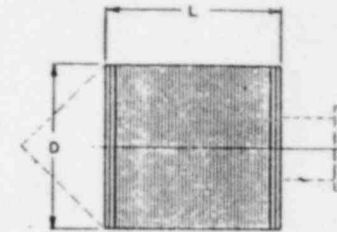
Fig. V-6 is a typical chart for sizing one type of small-opening cylindrical screen unit designed for an average inflow velocity of about 0.34 fps (0.10 m/sec). The chart also lists weights for single screen units. This chart is applicable only for No. 69 profile wire. Similar charts can be obtained from manufacturers for other wire sizes and screen configurations.

MISCELLANEOUS PHYSICAL EXCLUSION CONCEPTS

Other less promising physical exclusion systems have been studied extensively and are still being investigated. Among these are the following:

- a. Artificial filter beds, Fig. V-7. Engineering problems have to date not been resolved for large and fully reliable water withdrawals from such filters (15). The primary problem with artificial filters is their potential for plugging and the associated difficulty of providing a reliable backwash system. There are a few reasonably successful small installations associated with water supply withdrawals from clear water sources.

SCREENING FOR ORGANISMS



STANDARD SINGLE SCREEN DIMENSIONS & WEIGHTS

PART NUMBER	NOM SCREEN DIA D	OVERALL LENGTH L	APPROX WT OF SCREEN (POUNDS)
S12	12	14	65
S16	16	18	110
S18	18	20	135
S21	21	23	180
S24	24	26	250
S27	27	29	320
S30	30	32	410
S33	33	35	505
S36	36	38	595

NOTE: ALL DIMENSIONS GIVEN IN INCHES

Figure V-6 PROFILE WIRE SCREEN CHART

Courtesy of: Johnson Division UOP Inc.