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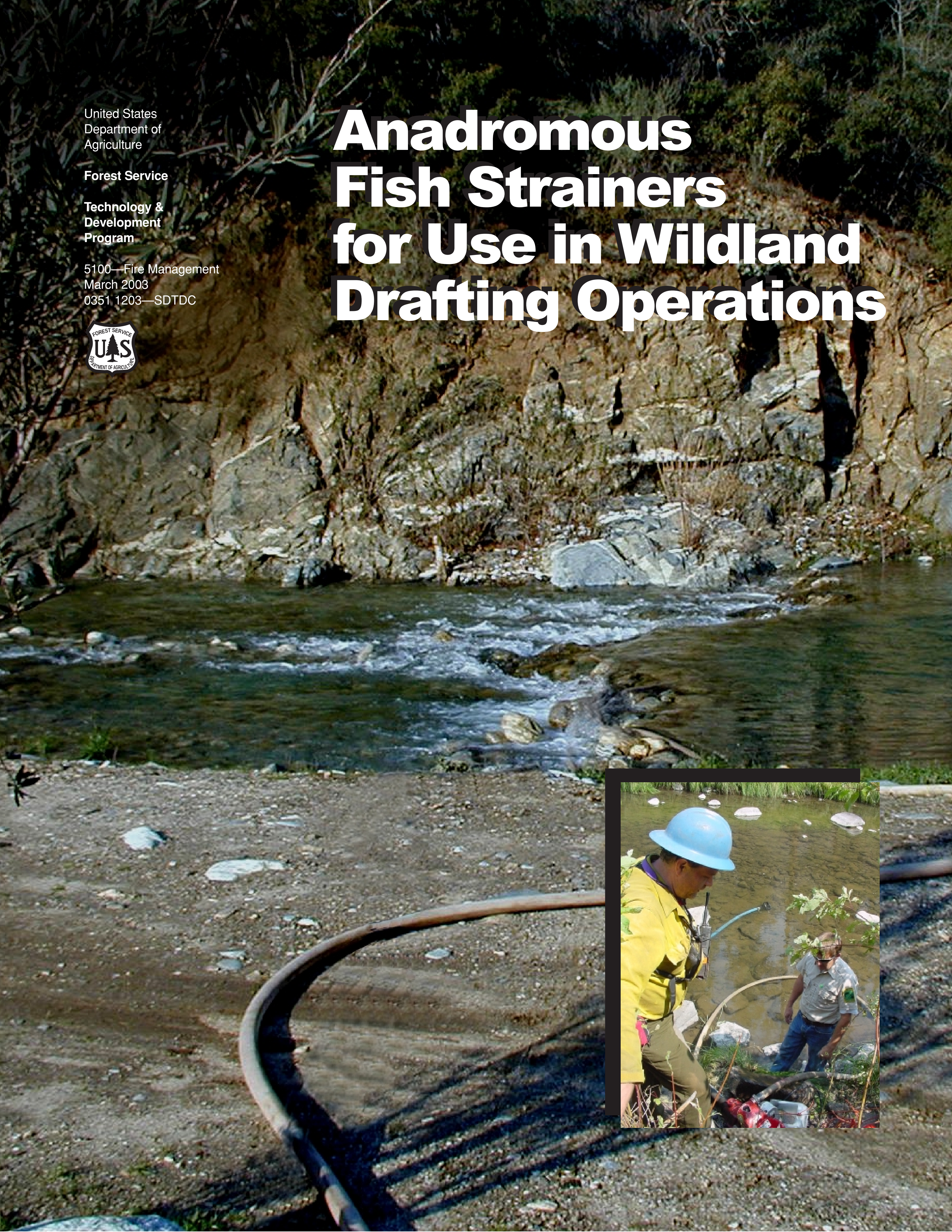
Anadromous Fish Strainers for Use in Wildland Drafting Operations



Anadromous Fish Strainers for Use in Wildland Drafting Operations

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Introduction and Scope

Anadromous fish—fish that return from the sea to rivers in order to breed—are being drafted into water-holding tanks used for fire suppression operations and project work. Many of the young fish are weak swimmers and are swept away during drafting operations; they eventually die. Over time, because so many juvenile fish are killed before they can reproduce, fish resources are depleted. To help the anadromous fish population, new Federal laws (i.e., Threatened and Endangered Species Act) and restrictions have been passed that protect fish and their natural habitats.

The enactment of these protective laws and restrictions has created a need for strainers for portable pumps, engines, and water tenders used in drafting during fire management operations. To allow time for developing suitable strainers, the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service in consultation with the U.S. Department of Agriculture (USDA) Forest Service had allowed fire drafting operations to continue provided the suction screen size was no greater than 3/32 in, and certain flow requirements were met. The project goal was to develop strainers for a variety of pump intake diameters that met screen size requirements and all other applicable regulations. No commercially available strainers met all established design criteria. San Dimas Technology and Development Center (SDTDC) staff developed and tested several prototypes in the laboratory that meet all the requirements and regulations. SDTDC selected a small- and large-spring fish strainer for final development. The final selection was based on the field evaluation for ease of use, maintenance, and refurbishment. The field evaluation included fish strainer use in drafting operations to support fire suppression activities, use by a road maintenance contractor, and use by a timber sale operator for road watering.

The prototype fish strainer consists of (1) a heavy wire spring, (2) a securing mechanism to the draft hose to maintain centerline, (3) a stint on the check valve to maintain a fully open spring position when in operation, and (4) a woven-fabric mesh covering with a tie string. The fish strainer's spring-and-buckle design makes it collapsible for storage. Laboratory and field-testing indicated that this appliance causes no disturbance to fish and minimal friction loss. This document includes instructions for strainer fabrication; however, this new fish strainer may become commercially available in the near future (figure 1).

Figure1—Fish strainer and components.

Scope of Water Drafting Equipment

Applying water is the preferred means for suppressing fire. Depending on location and conditions, helicopters and aerial tankers deliver water from streams and lakes by aerial drops. Typically, however, water is transported to fires via a water tender and/or tank truck, via a fire engine and/or pumper unit, or by portable pumps with a network of fire hoses. Firefighting operations use the closest water source available. For portable pump operations, the pump size varies with site conditions. Most units, however, are within the ranges indicated in table 1.

Table 1—Wildland fire pump capacity

Unit Type/ Model	Power Rating (hp)	Volume (gal/min)	Draft Hose Size (in)
Water Tender	5	263	3
BLM Engines	18 to 25	74 to 94	1½ to 2
FS Engines	18	72 to 95	1½
Mark 3	9	21 to 90	1½
Mark 26	5	5 to 84	2
Mini Mark	2	0 to 60	1½
Shindaiwa GP-45	2.3	0 to 66	1½
Shindaiwa GP-25	1.3	0 to 37	1½

Streamflows are not measurably affected by typical short-term water drafting operations. For example, it takes approximately 15 minutes to fill a water tender/ tanker, with smaller intermittent withdrawals for hose operations. If no adequate water source is nearby, portable storage tanks may be set up and filled by water tenders to supply pumping needs near a fireline. Locations for water drafting vary from small, first-order tributary streams or ponds, to larger fourth- or fifth-order streams, rivers, or lakes. Water drafting can occur from April through November, depending on fire situations; however, nationally, June, July, August, and September have the highest levels of fire operations.

Bucket- and fixed-tank helicopter water or retardant drops may be used to help check fire movements, as well as to knock down hotspots within the fire's perimeter. Helicopter buckets and fixed tanks can hold from 75 to 1,000 gal. Helicopters typically bucket water from ponds, lakes, and rivers that are near the fire. Fire equipment personnel select a suitable dip site based on safety criteria for the helicopter, and on water depth, area, and size. When suitable dipping locations are unavailable, a helicopter can load its bucket from portable holding and mixing tanks filled from a small water source.

Effects of Water Drafting Operations

In first-, second-, third-, and fourth-order streams, the use of portable pumps and water tenders could result in the harassment or take of threatened and endangered fish species through disturbance of staging or spawning adult fish, as well as the entrainment of juvenile fish. In the Salmon River sub-basin, listed fish species could be migrating, spawning, rearing, or overwintering at any time of the year. While helicopter bucket or snorkel operations may harass fish species, the risk of capture is usually minimal. It is proportional to the size of the stream, the size of the bucket, and the fright and/or flight responses of the fish encountered. In addition, river sites most suitable for bucketing operations are deeper, slower, mid-channel areas where smaller fish are unlikely to be encountered and larger fish tend to be near the bottom.

Occasionally, fire personnel may use pools or deeper runs in larger streams for helicopter bucket or snorkel operations. Use of tributaries has a higher risk of entrainment and a greater potential for harassment. Given the infrequent occurrence of fires, the periodic incidence of helicopter bucket or snorkel operations, and the large area of the sub-basin, however, the risk potential for any single taking is low to unmeasurable. Ongoing field monitoring of water withdrawal sites during fire operations is needed to confirm fish presence or absence, life stage, activity level (spawning or rearing), and the proper use of intake screens to ensure protection or mitigation for site-specific situations.

Regulations Regarding Anadromous Fish and Drafting Operations

The applicable regulations were determined and design criteria developed over a line of strainers with varying diameters that meet the current regulations and are commercially available or easily assembled from commercially available materials. In the use of water handling equipment in wildland drafting operations, these laws appear in Section 18 of the Federal Power Act, administered by the Federal Energy Regulatory Commission (FERC) along with the NMFS and its responsibilities for defending fish under the Endangered Species Act (ESA). (Appendix A). These new regulations are described in terms of approach velocity, sweeping velocity, applicable screen opening, screen percent open area, and other applicable regulations in the use of water handling equipment for wildlife and drafting operations.

Screen Technology

The anadromous fish strainers designed for this project meet all the applicable regulations and screen criteria described in this report.

Approach velocity is the component of water velocity perpendicular, at 90°, to the screen surface and about 3 in from that surface. Flow through the screen shall be distributed evenly so that the maximum approach velocity is not exceeded. Designs with nonuniform approach velocity may require additional screen area. To reduce the risk of juvenile fish becoming trapped against the screen, it is crucial that the fish be able to swim faster than the approach velocity for an extended period of time. For salmonid fry (less than 2.4 in. in length), the maximum approach velocity for a passive pump is 0.20 ft/s; and for salmonid fingerlings (more than 2.4 in. in length), the maximum approach velocity for a passive pump is 0.40 ft/s. The approach velocity is based on the effective screen area, which is calculated by subtracting the screen area obstructed by structural members from the total screen area. Note, however, that the approach velocity is calculated based on the gross screen area, not on the net open area of the screen mesh.

For small juvenile fish screens/strainers with a required approach velocity of less than 1 or 2 ft^3/s (less than 450 to 900 gal/min), it is appropriate to overestimate the maximum flow rate, and increase the required intake screen area. Increasing the screen surface area decreases the approach velocity on the screen face, which reduces the chances of trapping a fish against the screen, and aids the screen-cleaning system. The best way to select the maximum flow level is to obtain flow records, which are usually available from the municipal water district.

Flow that pushes through the screen mesh accelerates due to the contraction through the mesh; the hydraulic term is "veni contracta." As a result of the acceleration, the velocity through the screen mesh will be higher than the velocity just upstream of the screen mesh, because the friction and geometry effects create some head loss through the mesh.

When the NMFS developed the criterion for approach velocity, biological testing involved a calculation of approach velocity about 3 in. in front of a screen mesh, upstream of the flow contraction. This test screen mesh was a flat plate mesh oriented perpendicular to flow, and a resulting relationship between velocity normal to the screen face and 3 in. in front of the screen face (i.e., approach velocity) and fish swimming ability was developed. This approach velocity works well because fish can detect the acceleration of flow through the mesh and can usually avoid direct contact.

Sweeping velocity is the component of water velocity that moves parallel to the screen surface. High sweeping velocity reduces the chance of fish capture in the screen. Therefore, the sweeping velocity must be greater than the approach velocity. To minimize sediment accumulation in or around the screen and to assist with fish moving away from the screen face, intakes shall be located in areas with sufficient sweeping velocity. Because sweeping velocity is not a requirement for strainers uniform in diameter, this new fish strainer was designed to be cylindrical with a uniform diameter.

Screen openings may be round, square, rectangular, or any combination thereof, as long as they do not interfere with cleaning. Screen mesh material and support structure shall work in tandem to withstand the harshness of the installation site. It is important that the screen material be resistant to corrosion and ultraviolet damage and be able to maintain a smooth, uniform surface with long-term use. A smooth surface helps reduce injury to fish that may hit the screen, reduces turbulence, and prevents eddies.

NMFS developed dimensional criteria for the most common screens—woven wire mesh, perforated plate, and profile bar screens—with specifications for fabric screen material (figure 2). Screen opening size and percent of open area for the fabric material are the same as for the perforated plate. The screen opening size is the *stretched* size.

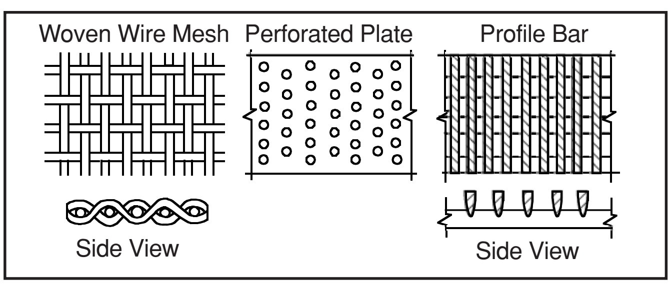

Figure 2—Woven wire mesh, perforated plate, and profile bar screens.

All drafting operations shall use a screen to accommodate salmonid fry, unless they can show an absence of fry-sized salmonids in the area. (Table 2.) Some screen manufacturers use other materials, such as monofilament mesh or plastic mesh. Some drafting operations may require screening media that inhibits aquatic growth, such as phosphor-bronze mesh, to help prevent fouling in areas with algal growth problems.

Table 2—Criteria for the screen (according to NMFS)

Type of Fish	Perforated Plate Screen	Profile Bar Screen	Woven Wire Mesh Screen	Minimum Percent of Open Area
Salmonid fry (Length less than 2.4 in)	Openings cannot exceed $^{3}/_{32}$ or 0.094 in	Narrowest dimension cannot exceed 0.069 in	Cannot exceed $^{3}/_{32}$ or 0.094 inch in the narrowest direction	27
Salmonid fingerlings (Length more than 2.4 in)	Openings cannot exceed 0.25 in	Narrowest dimension cannot exceed 0.25 in	Cannot exceed 0.25 in. in the narrowest direction	40

Note: Screen mesh opening is the narrowest opening in the screen mesh. The maximum openings and narrowest dimensions apply to the entire screen structure, including screen mesh, guides, and seals.

Positive Barrier Screens

Positive barrier screens are physical barriers that are used in the Pacific Northwest for fish protection. Rotary drum, vertical traveling, and pump intake screens are positive barrier screens.

A pump intake screen, which is connected directly to a pressurized system, can be either active or passive. An active pump intake screen is connected to a cleaning system. Options for active pump intake cleaning systems are (1) fixed screen with a rotating spray bar, (2) fixed spray bar with a rotating screen, or (3) an internal airburst. All three options have operated successfully when the cleaning system was customized for a particular design.

A passive pump intake screen is not connected to a cleaning system and, therefore, requires manual removal of debris. Because USDA Forest Service mobile pumps have passive pump intake screens, the anadromous fish strainer design focused on passive pump intake screening devices.

Passive Pump Screen Submergence Regulations

To achieve the proper water velocities, screens must have a minimum submerged screen area during lowest streamflows that may not include any area that is blocked by screen guides or structural members. If the water level changes, the screen must be checked for proper submergence.

The following formula calculates the total submerged screen area required:

$$\text{Minimum Total Submerged Screen Area Required} = \frac{\text{Diverted Flow } (\text{ft}^3/\text{s})}{\text{Approach Velocity } (\text{ft/s})}$$

Conversion: 450 gal/min = 1.0 ft^3/s

Maximum Approach Velocity = 0.2 ft/s

For passive pump screen diversions/drafting, water that is turned from its natural path, that is less than or equal to 90 gal/min requires a minimum submerged screen area of 1.0 ft^2.

Preferably, a pump intake screen/fish strainer is positioned vertically and submerged to a depth of at least one screen radius below the minimum water surface, with a minimum of one screen radius clearance between the screen and any obstacles. This is easy if a flotation device is tied to the strainer/draft hose and is positioned vertically in a stream with a water depth of greater than 14 in for a small strainer and 24 in for a large strainer.

A typical drafting operation in wildland firefighting is in shallow streams of only 1-ft deep, with the strainer positioned at an angle. In this shallow application, the NFMS requires that the strainer be positioned at an angle at least 1-in below the water surface provided two-thirds of the stream volume is available for fish to escape. Effectively, two times as much water must run past the strainer as runs through it to ensure a clear escape route for fish. In addition, 100 percent of the stream water must go through the mesh strainer. Consequently, the mesh bag must be tied securely to the draft hose, preventing fish from slipping into the strainer at the bag opening. To protect the pump intake from debris, the strainer may be placed on a shovel laying on the streambed (figure 3).

Figure 3—Pump intake screen submerged at the appropriate depth with clearance between the screen and any obstacles.

Passive Pump Fish Strainer Design Criteria

The primary consideration in developing design criteria for anadromous fish strainers for use in wildland drafting operations is the swimming ability of the local fish. The swimming ability of fish depends on variables such as water temperature, sex, and species. The most common anadromous fish are salmon, which is why they were tested; other types are cutthroat trout, steelhead, American shad, sturgeon, and Pacific lamprey. Much of the available information on fish species' swimming capabilities is generalized because not all species of anadromous fish have been tested.

According to the Washington Department of Fish and Wildlife (WDFW), the information for the maximum approach velocity and screen mesh opening criteria is based on the swimming stamina of emergent fry size salmonids in low water temperature conditions, the most vulnerable condition. Some locations may not require designs for these conditions; however, it is assumed that these extreme conditions exist at some time during the year at all screen sites.

Fish Strainer Design Criteria

Strainer design criteria were developed for passive pumps based on the regulations and drafting equipment currently in use in wildland fire operations. The anadromous fish strainers were designed to meet the criteria that follows:

1. Strainers must
   - Meet the current applicable Federal, State, and local regulations and administrative acts.
   - Consist of lightweight, durable, and easily assembled components.
   - Maintain or enhance safety at low maintenance levels and low cost.
2. Strainers should
   - Be readily available commercially or from easily fabricated commercial components.
   - Be easy to use, with minimal training required.
   - Consist of one-size-fits-all drafting applications that are not bulky and are collapsible, if possible.
   - Have a suction diameter size of $1^1/_2$ in and $2^1/_2$ in as typically used in wildland fire services.
   - Have a pump discharge flow range of 0 to 263 gal/min (table 1).

- Afford a clear escape route for fish. Undesirable alterations to riverine habitat shall be minimized.

3. Pump Intake Screens should
   - Be capable of being submerged to a depth of at least one screen radius below the minimum water surface, and between the fish strainer and any obstacles, including the bottom of the stream.

   - For screens less than or equal to 90 gal/min, the minimum submerged screen area must equal at least 1.0 ft^2 and the whole strainer must be submerged for a depth of at least $3^1/_2$ in from the strainer top, when the strainer is 7 in. in diameter.

   - For screens greater than 90 gal/min and less than 320 gal/min, the minimum submerged screen area must equal at least 3.6 ft^2 and the whole strainer must be submerged for a depth of at least 5 in from the strainer top, when the strainer is 10 in. in diameter.

   - Be equipped with mesh openings of perforated plate or woven mesh less than or equal to $^3/_{32}$ or 0.094 in. Minimum diameters for woven mesh shall be 0.080 in (14 gauge) in areas subjected to debris and 0.60 in (18 gauge) in areas not subjected to debris. The maximum openings and narrowest dimensions apply to the entire screen structure, including screen mesh, guides, and seals.

   - Provide a screen with a minimum of 27 percent of open area.

   - Approach velocity at passive pump intake screen of less than or equal to 0.2 ft/s.

   - Provide a sweeping velocity at the screen that must be at least double the approach velocity, unless the strainer is uniform in diameter. Locations with the proper sweeping velocities are ideal to help push away fish and debris from the screen face. For screen lengths less than 4 ft and less than 25 ft^3/s, the screen may be angled or perpendicular to the relative flow.

   - Incorporate a screen design that accommodates the screen mesh size and maximum velocity regulations to protect the weakest swimming fish species in their most vulnerable life stage, under the harshest environmental conditions.

   - Maintain a screen face exposure to fish for less than 1 min.

   - Employ an oversized screen for protection from heavy debris, icing, and other conditions that may compromise screen integrity.

   - Incorporate a reliable cleaning system capable of removing debris over the entire screen mesh. Fish screens shall be cleaned as frequently as necessary to prevent obstruction of flow and violation of the approach velocity criterion. Screens designed with greater area reduce the time between required cleanings whether screens are cleaned manually once or twice throughout the day, or at longer intervals.

   - Resist corrosion and ultraviolet damage and shall be able to maintain a smooth uniform surface with long-term use.

   - Employ sufficiently durable screen mesh material and support structure that shall work together to withstand the rigors of the installation site.

Passive Pump Anadromous Fish Strainer Designs

The SDTDC project engineer developed a spring-type passive pump screen fish strainer that meets the desired design criteria, including required flow and drafting conditions encountered in typical USDA Forest Service drafting operations. The small strainer is designed to accommodate a flow rate up to 95 gal/min and the large strainer accommodates flows up to 265 gal/min.

Small Spring Fish Strainer Description

Capabilities

- This strainer is designed for flow rates of 95 gal/min with an approach velocity of 0.16 ft/s.
- The ultimate allowable flow rate is 115 gal/min with an approach velocity of 0.2 ft/s.

Dimensions

- Length = 7 in, Diameter = 7½ in.
- Collapsed length = 3 in.
- Screen Area = 1.29 ft^2 (this is 22 percent more area than required due to clogging factors, flow obstructions when on a lake or stream bottom, and unpredictable nonuniform flows).
- The maximum allowable distance between strainers in a multiple-pump drafting operation is 8 in.
- The small spring strainer needs to be positioned at least 4 in off the lake bottom, placed in a shovel, or floated with a flotation device/log.

See appendix B for detailed fabrication instructions. See appendix C for setup and use.

Large Spring Passive Pump Screen Fish Strainer Description

Capabilities

- This strainer is designed for flow rates of 265 gal/min. The ultimate allowable flow rate is 320 gal/min with an approach velocity of 0.2 ft/s.

Dimensions

- Length = 13 in, Diameter = 10 in.
- Collapsed length = 3½ in.
- Screen Area = 3.57 ft^2
- The maximum allowable distance between strainers in a multiple-pump drafting operation is 10 in.
- The large spring strainer needs to be positioned at least 5 in off the lake bottom, placed in a shovel, or floated with a flotation device/log.

See appendix B for detailed instructions for fabrication. See appendix C for setup and use.

Laboratory Testing

SDTDC conducted laboratory testing to evaluate various design configurations. A minor (up to 2 percent decrease in flow) difference exists due to increased friction loss with the use of the small fish strainer in conjunction with a 1½- in foot valve as compared to the foot valve alone. There is essentially no change in flow with the 2½-in foot valve and a foot valve with large fish strainer. See appendix D for performance charts.

Field Evaluations

SDTDC conducted field tests to finalize the design and identify issues. The prototype fish strainers were used in drafting operations primarily in support of fire suppression activities. A road maintenance contractor and a timber sale operator also used the prototype for road watering.

Fire personnel used small and large fish strainers in many wildland fire suppression operations. Although the strainers were distributed with instructions for use, fire crews received the strainers without the instructions, which is not unusual on a fire application. Oregon Department of Fish and Wildlife fish biologists Jon Germond and Tim Bailey found that the strainers were not fastened tightly to the hose. The tie cord must be secured tightly enough around the draft hose to restrict water from entering the strainer without going through the fabric mesh, preventing fish from being introduced into the strainer at the bag opening. On one fire, the drawstring at the top of the mesh net did not seal well when attached by firefighters. Field experience revealed that using an open-ended cord, rather than a continuous-loop design, and wrapping it several times around the bag/strainer/draft hose made an effective seal, restricting water from entering the strainer through the mesh bag/draft hose interface (figure 4).

Figure 4—Mesh bag/draft hose interface.

Buckles sometimes were not released to expand the strainer to the fully open position. The strainer in the fully collapsed position, however, did not disturb fish and there was no apparent change in performance during drafting operations. These experiences show that instructions for use need to be distributed widely. This report will be distributed nationally and to multiple agencies by hard copy and via the Internet for use in training regarding the care, use, and maintenance of the anadromous fish strainer.

Kevin Blakely of the Oregon Department of Fish and Wildlife reported that fish strainers were used in a portable tank fill operation with three pumps filling a dip tank used by two heavy helicopters working on 3½ min turnaround. Three low-pressure, high-volume pumps ran continuously to keep up with the helicopter draw. Two pumps were placed side by side for drafting from a creek in a water pool that was 2 ft deep, with little sweeping velocity, a common operation. In side-by-side drafting operations, 8 in is the minimum allowable distance between strainers. The strainer needs to remain at least 1 in below the waterline and preferably 4 in off the creek bottom. If the water is deep enough, the strainer/foot valve may be suspended in the water and floated off the creek bottom using a flotation device or log secured to the draft hose. One pump operation ran a full day without the strainer requiring cleaning and did not clog. The stream bottom was cobbled, with algae covering the rocks. There was very little mud, silt, or organic debris to filter. The fire crews were happy to use the strainers and seemed eager to protect the fish.

On a sandy lake bottom, the fish strainer seemed to prevent sand from being drafted into the system. In the fully extended position, the strainer is 7 in long, with the foot valve positioned about 3 in from the bottom on the strainer and off the lakebed. In addition, the preferable strainer location is at least 4 in off the lake bottom, or in a shovel, further preventing the introduction of sand and debris.

The strainer was used in streams with mud and organic debris to provide feedback on clogging. A fire crew put a burlap bag around the strainer to prefilter the water when pumping out of a mucky pond with a Mark 3 lightweight portable pump. Tony Pastro of Alaska Fire Service said this works well in all but the worst water sources. Burlap bags prefilter the mucky water. Debris clings to burlap, but water can still work though with no apparent loss in flow.

Burlap bags cost around 85 cents each and can be inexpensive disposable filters. It is recommended that at least two burlap bags be carried, to be switched with minimal interruption of drafting operations. By spraying with a nozzle from the inside of the burlap bags, to remove the debris clinging to the outside, burlap bags become reusable.

The original field prototype design included a foot valve extension/spacer to maintain the full expansion of the strainer when it was in the water with the weight of the suction hose from the top. In some of the field tests, the foot valves with extensions were not used. Firefighters were not reluctant to use the modified foot valves; they just did not bother to grab one. It was discovered that the foot valve extension was unnecessary. The internal spring kept the strainer fully open when it was submerged.

The sweeping velocity is not a consideration if the strainer is uniform in diameter. Consequently, the fire crew did not consider the sweeping velocity of water past the screen when looking for a site to deploy the pumps. In most cases the pumps will be deployed in the best place to pump and fill without consideration for water flow past the screen. The resource advisor can follow up with suggestions on hose placement but expect the first few days or hours of operation to be without consideration for fish in stream placement.

All fire crews using the fish strainers were very pleased with its performance, resulting in several procurement requests for the strainers. The prototype has been finalized, and a production model has been developed and sent to manufacturers for consideration for commercial availability.

Cleaning a Passive Pump Intake Screen

An active pump intake screen is equipped with a cleaning system and is cleaned as frequently as necessary. A passive pump intake screen, however, has no cleaning system and should be used only when debris is low, and one of the following conditions is present:

1. With small screen, less than 450 gal/min or 1 ft^3/s pump, is oversized to eliminate debris;

2. Sweeping velocity exists to eliminate debris on the screen surface;

3. Maximum diverted flow is less than 0.01 percent of the total minimum stream flow; or

4. Intake is deep in a reservoir, away from the shoreline.

Proper and preventive fish screen maintenance, such as cleaning away debris or checking seals for wear, is as important as a good-quality screen design. When debris accumulates on or around the screen, it affects the effective screen area and increases the approach velocity. With the change in the approach velocity, fish are no longer able to move away voluntarily from the screen and may become trapped. Debris can also clog tubes and cause eddies to form around the screen. If an eddy forms, it may delay or injure the fish or may provide a location for predators to attack. Proper maintenance of the strainer includes the following:

1. Clean fish strainers as frequently as necessary to prevent accumulation of debris, which obstructs flow and may violate the approach velocity criterion. Remove the fish strainer from the water and clean with a high-pressure spray or by manually scrubbing with a brush. In debris-laden water, use a burlap bag over the strainer as a prefilter to inhibit clogging and to further quick and easy cleaning. Cleaning the strainer requires longer downtime than switching out a burlap bag.

   Carry at least two burlap bags and switch them as often as necessary. Burlap bags can also be considered disposable. Replace the burlap bag with another with minimal interruption of drafting operations. The clogged burlap bag can be cleaned easily for reuse by spraying it from the inside out.

2. Protect the fish strainer and pump intake screen from heavy debris, icing, and other conditions that may compromise screen integrity. Perform routine strainer inspections for debris accumulation and removal as appropriate. The strainer needs to be cleaned manually once or twice during the day, or at longer intervals to help keep the approach velocity at 0.2 ft/s.

Efforts To Improve Water Drafting Operations

1. Fire staff and fisheries specialists should develop a prefire suppression plan to identify drafting areas sensitive to anadromous fish species. They should map the unapproved areas and state at which point in fire suppression activities the area is allowed to be used for protection of life and property.

2. To preclude the entrainment of juvenile fish seeking thermal refuge, or the potential harassment of adult fish preparing to move into a tributary for spawning, water drafting and helicopter bucket or snorkel operations should avoid locations within 100 yd of stream confluences.

3. To preclude stream or lake contact in the event of a tank failure, it is acceptable to place temporary holding and/or mixing tanks, provided there is at least a 100-ft setback for chemical mixing tanks. Plain water holding tanks can be located within 100 ft of a water body.

4. In poor water sources, use logs to float the foot valve near the surface into the cleaner water to inhibit debris clogging and to reduce the frequency of strainer cleanings. Clean strainers at least once a day and as indicated.

5. Issue and operate water pumps with anadromous fish strainers, where appropriate. Inspect independent water haulers to determine whether they are equipped with an appropriately sized anadromous fish strainer.

Checklist for Improving Use by Minimizing Effects of Anadromous Fish Strainers in Drafting Operations

1. Use fire suppression techniques that minimize effects to aquatic and riparian habitats. Avoid aquatic habitat disturbances, including sedimentation, decreasing shade vegetation, chemical contamination, and increasing fish mortalities.

2. The fire fisheries resource advisor will provide a map for acceptable water drafting or helicopter bucket and snorkel operation locations. Generally, avoid such operations within 100 yd of stream confluence areas and use an anadromous fish strainer on all pumps and water tenders. Use at least a 100-ft setback from streams for chemical mixing tanks. Plain water holding tanks can be located within 100 ft of a stream.

3. For fire rehabilitation include mitigation for both short- and long-term impacts potentially affecting aquatic habitat, as identified by the fire fisheries resource advisor during development of the rehabilitation plan.

Manufacturer Information

Several manufacturers carry small and large fish strainer prototypes for use in developing a commercially available product. The final manufactured fish strainers will be performance tested before notifying the field of commercial availability and procurement information.

For further information, please contact the fire program leader at 909–599–1267.

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Appendix A
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Appendix B
Detailed Instructions for Fabrication

Detailed Instructions for Fabrication

Method for Assembling Small and Large Spring Fish Strainers

Materials.

- $\frac{1}{2}$-in wide by $\frac{1}{8}$-in thick metal bar purchased at a hardware store in various lengths.
- 8-32 screws $\frac{5}{8}$-in long, and bolts (if not welding)
- Wrapping wire—any gauge thickness
- Duct tape
- Spring (SDTDC used a product from Toys-R-Us called a "see-me-connecting-tunnel" by Pacific Play Tents Inc.)
- Zip ties—small enough to fit through the mesh material.
- Mesh Material (Textile Outfitters, phone 403–543–7676. Black, heavy-duty, vinyl-coated nylon mesh with mesh opening size of less than or equal to $\frac{3}{32}$ in.
- Drawstring
- $\frac{1}{8}$-in diameter metal crossbars

Instructions

- Cut mesh fabric for sewing (figure B1).
    A. Small Spring Fish Strainer
        1. Rectangle—25 in by 18 in
        2. Circle—9$\frac{1}{2}$-in diameter
    B. Large Spring Fish Strainer
        1. Rectangle—24 in by 36 in
        2. Circle—12-in diameter

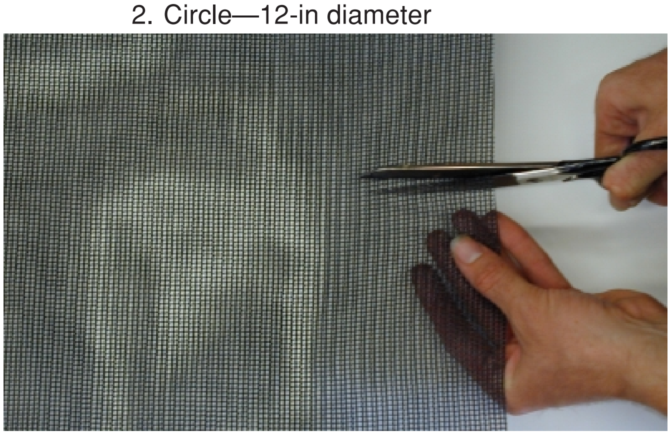

Figure B1—Cutting mesh fabric for sewing.

- Overlap top material by 2 in and sew a drawstring casing (figure B2).

Figure B2—Overlap top material and sew a drawstring casing.

- Cut metal bars into 24$\frac{1}{2}$-in and 32$\frac{1}{2}$ in sections for small and large strainers, respectively, if *bolting* together. If *welding* together, cut 23$\frac{1}{2}$-in and 31$\frac{1}{2}$-in sections respectively. The difference is due to overlap when bolting together (figure B3).

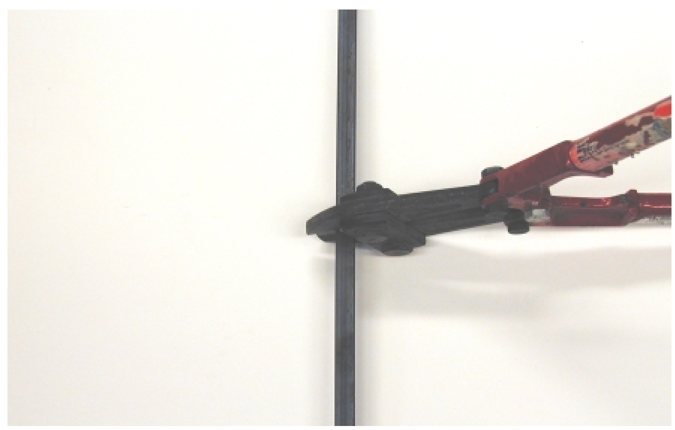

Figure B3—Cutting metal bars.

- If bolting the rim together, drill an $\frac{11}{64}$-in hole $\frac{1}{4}$-in from each end of the metal bar. Use cutting fluid.
- Bend the rim in uniform circular shapes of 7$\frac{1}{2}$-in and 10-in diameters.
- Fasten the rim together with the screw and nut, leaving the nut on the inside of the rim, or weld.

- Locate the proper spots for the crossbars on one of the rims (figure B4).

Figure B4—Locate proper crossbar spacing.

- Wire down the crossbars with bending wire or weld.

- Place two layers of duct tape over the wire or sharp edges (figure B5).

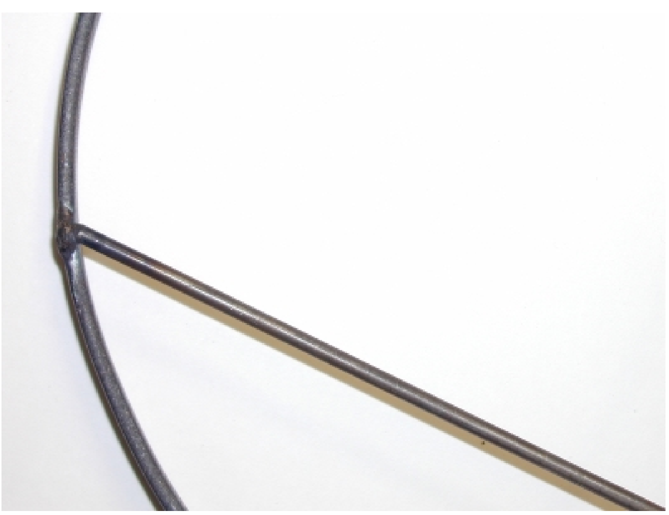

Figure B5—Place two layers of duct tape over wire or sharp edges.

- Wire and tape or weld the spring to the rims in three places.

- Compress rim/spring unit to make sure the spring is inside the rims. Bend spring if necessary. (figure B6).

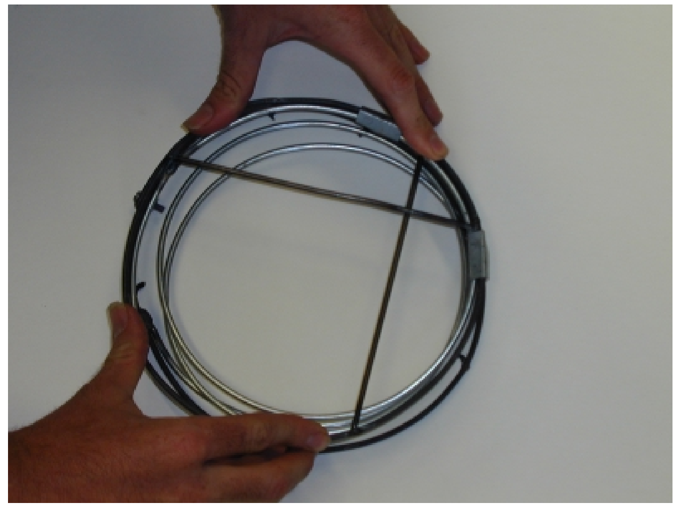

Figure B6—Checking rim/spring location.

- Place the sewn bag over the unit.

- Use the zip ties to place the rims at the correct height, 7 in (small spring) and 13 in (large spring). (figure B7).

Figure B7—Use of zip ties tosecure rim at correct spacing.

- Place the zip ties around the rim, spaced 1½-in apart.

- Zip tie ends will be on the inside of the strainer.
- Cut off the excess zip tie.
- Clip zip tie on the sides of the rim—180° separation—tie the female end of the clip to the upper rim with crossbars on it (figure B8).

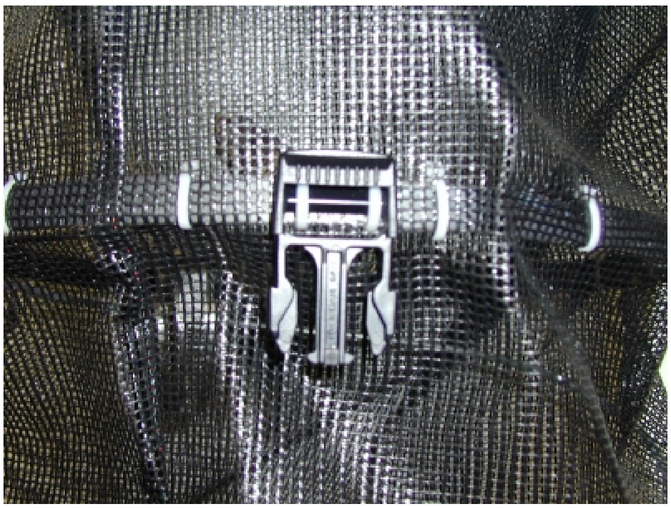

Figure B8—Clip attachment held with zip ties.

Appendix C
Setup and Use

Setup and Use

Part A. Add an extender onto the foot valve to hold the strainer in the fully open position and install a hose clamp with carabiners.

Materials

- Two 6-in, 8-32 screws
- One jar lid
- Two 1¼-in washers
- Two ¾-in washers
- Six 1-in by ½-in nylon spacers
- Two 5-15 by 1¾-in carabiners
- One radiator hose clamp fitting a 1½- or 2½-in diameter, depending on foot valve size

Assembly Instructions

- Unscrew the two screws in the bottom of the current USDA Forest Service foot valve.
- Place the small washers on the new, longer screws.
- Place the larger washers or the jar lid on the new, longer screws.
- Place three nylon spacers on each of the new, longer screws.
- Insert the new, longer screws with spacers and washers on the bottom of the current USDA Forest Service foot valve/strainer.
- Screw in the new, longer screws with a flathead screwdriver until screws are tight.
- Unthread the hose clamp completely until it is no longer circular.
- Place two carabiners through the hose clamp.
- Rethread the hose clamp.
- Place the hose clamp over the top end of the foot valve/strainer, making sure the open part of the carabiner is oriented near the top of the foot valve/strainer.
- Tighten the hose clamp ¼-in from the top of the foot valve/strainer screen.

Part B. Assemble foot valve into strainer and close off mesh bag.

Take a spring strainer with buckles and support bars; and a 1½-in foot valve with an extender, hose clamp and carabiners as described in part A.

1. Open the fish strainer to the fully open position by releasing the buckles on the side of the closed strainer, by pushing in the tabs on the side of the buckle.
2. Insert the foot valve into the strainer and connect each carabiner to a support bar inside the strainer.
3. Tighten the bag drawstring and rewind the string around the draft hose so it is 100 percent closed.

Construction Components

- Two rims are fastened to a compression spring.
- A cross-pattern of two metal rods is attached to the upper rim for the points of attachment.
- The foot valve has two carabiners fastened to it. These attach to the cross-pattern. They are spaced at one-quarter of the distance around the suction hose.
- Zip ties firmly hold the mesh to the rims.
- Two pairs of clips are fastened to opposite sides of the rims.
- The foot valve has a stint to prevent the spring from compressing and losing shape while drafting.

Instructions

1. Attach foot valve to suction hose.
2. Unclip the spring.
3. Clip the foot valve to the cross-pattern in one smooth motion.
4. Tighten the drawstring.

Approximate English to Metric System Conversion Factors used in this document

To Change	To	Multiply by
inches	millimeters	25.4
feet	meters	0.305
feet per second	meters per second	0.305
square feet	square meters	0.093
cubic feet per second	cubic meters per second	0.028
gallons	liters	3.785
gallons per minute	liters per second	0.063
horsepower	watts	745.7