Part 5

DECREASE IN PHYSICAL FACTORS IMPACT FROM POWER OBJECTS ON ENVIRONMENT

5.2. Fish protection technologies and constructions in power engineering

5.2.1. A choice of the optimal construction of fish protection structure for the certain water intake

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According to sanitary norms and rules SNiP 2.06.07 – 87 "Retaining walls, shipping locks, fish-ladders and fish protection structures" fish protection structures (FPSs) should be provided for means of prevention from ingress, injuring and death of larvae and the young fish at water intakes and for means of their withdrawal into a fishery basin. [1]

The key concepts of this statement are:

1. Prevention from ingress and death of larvae and the young fish at water intakes.

It means that fish protection system must include actions and constructions, allowing no ingress of fish into a water intake.

2. Prevention from injuring of larvae and the young fish.

It means that at fish protection there should be no contact with protective-water receiving surface, resulting in their injury or death.

3. Withdrawal of fish into a fishery basin.

It means that it is necessary not only to stop fish near to the water intake, but also to withdraw it from this intake into a safe place.

It follows from what has just been said above, that for meeting all the requirements, set for FPSs, it should include a complex of elements, sequentially fulfilling the next functions:

- income, stream forming function, that provides redistribution of the young fish, rolling down to a water intake aside from the protective-water receiving surface of FPS;
- working, protective-water receiving function, that provides a uniform speed mode of water withdrawal to the consumer and prevention form ingress of fish into a water intake;
- outcome, fish-withdrawal function, that provides withdrawal of protected fish out of an action zone of the water intake into a safe place of a fish habitable basin.

In other words FPSs should include three main functional elements; income, stream forming; working, protective-water receiving and outcome, fish-withdrawal (Fig.5.43).

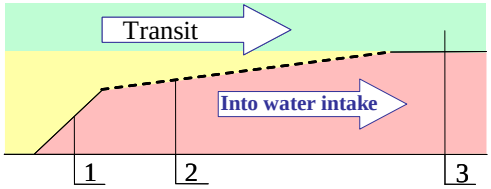


Fig. 5.43. A structure of the withdrawal FPS:
1 — stream forming element; *2* — working organ (protective-water receiving element); *3* — fish withdrawal element

For creating FPSs, at most meeting all the requirements set for fish protection, there was designed a method of optimal FPS construction choice for the certain object [2]. For this FPS development was suggested to realize by a three-staged scheme "Income – action – outcome". It allows to consider FPS in form of multicomponent complex, consisting of three main (income, stream forming; working, protective-water receiving and outcome, fish withdrawal) functional, and also auxiliary elements.

The method includes:

- division of FPS into components - its main functional (income, stream forming; working, protective-water receiving and outcome, fish withdrawal) and auxiliary elements;
- classification and analysis of each functional elements separately;
- joint examination of the most acceptable types of functional elements for the object, equipped with fish protection, regarding to its best compatibility in the set conditions (water intake, hydrology, ichthyology, etc.) aimed to get the optimal characteristic (fish protection efficiency, capital and operation costs, etc.);
- combination from them of a three-component FPS construction;
- its adding by a complex of auxiliary elements, if required;

By this, a stream-forming element, intended for forming of the hydraulic structure of stream, needed for effective contactless protection of the young fish, is the main functional element of the structure that affects a character of redistribution of the young fish in it into a transit fish transporting zone of stream. Practically, it defines the construction of the whole FPS by fixing in it of a disposition zone of other main functional elements: working and fish withdrawal.

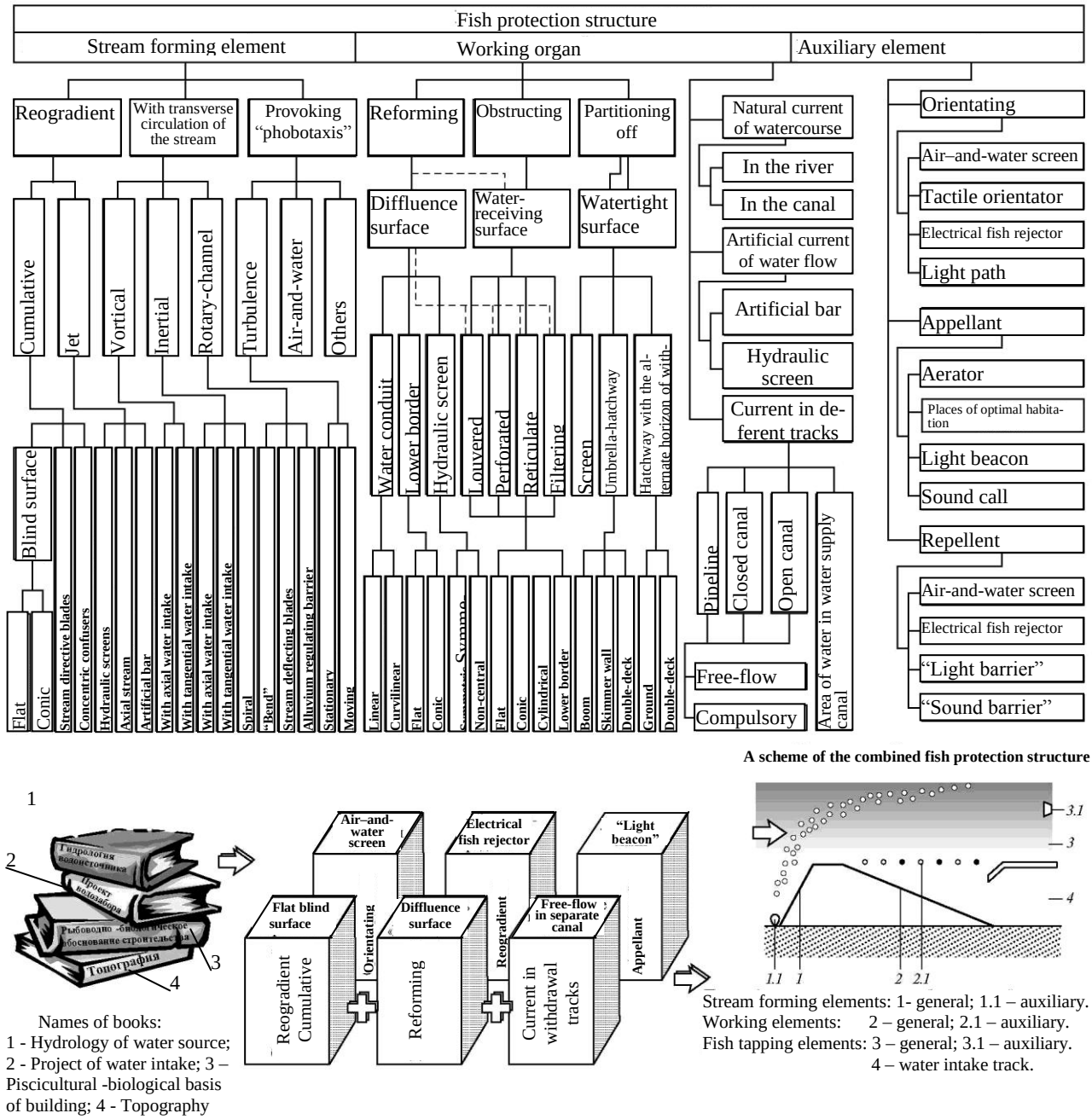
Working element (organ) is intended for providing the optimal conditions of passive flowing of the young fish in the transit stream into a fish withdrawal in a zone of water intake impact and uniform speeds of water withdrawal from the transit stream into a water intake that does not exceed the speeds, carrying away the protected fish.

Fish withdrawal element (fish withdrawal) is intended for withdrawal of the protected viable young fish from a zone of the working organ action into a safe place of a fish habitable basin.

Auxiliary elements add and improve fish protection and operational performances of its appropriate functional elements as well as FPS, as a whole.

Such approach allows designing of optimal FPS constructions for water intakes of any productivity and purpose, located at any fishery basins and watercourses, arranging by this a contactless protection of the young fish with withdrawal from the water intake of the not injured and viable fish for the next natural reproduction.

Having imagined a FPS as complex of functional elements, being a part of it, let's consider each element separately. **Stream forming element of FPS** is a main element of the construction, not only composing a definite hydraulic structure of stream for the certain FPS, but, mainly, affecting the character of redistribution of the young fish inside the device into its definite zone. Therefore, since it's intended for arrangement of such a hydraulic structure of the stream, incoming in the device, at which the young fish is being redistributed into its transit zone, it's reasonable to consider this element by a character of its impact on the structure of transit stream flowing.



A scheme of the combined fish protection structure

Names of books:
1 - Hydrology of water source; 2 - Project of water intake; 3 – Piscicultural -biological basis of building; 4 - Topography

Stream forming elements: 1- general; 1.1 – auxiliary.
Working elements: 2 – general; 2.1 – auxiliary.
Fish tapping elements: 3 – general; 3.1 – auxiliary.
4 – water intake track.

Fig. 5.44. Structural classification of the reforming FPS and a method of optimal FPS construction choice, based on its application

Ensuring of redistribution of the young fish in stream is possible by forming the following hydraulic structures of its flowing:

- reogradient;
- with the transverse circulation;
- provoking "phobotaxis".

Reogradient structure of stream is characterized by presence of zones with different speeds of flowing, possessing different ability of the young fish transporting. In its turn, only the increased transporting ability of the transit fish withdrawal stream provides effective movement of the young fish aside of water receiving surface of the working organ into a cap of fish withdrawal and then out of the water intake affection zone. Reogradient structure of stream could be formed either by placing inside the watercourse of stationary stream forming elements (gradients, confusers, etc), creating the stream with high speed in its certain zone, or by feeding of a high-speed stream from autonomous stream-generators or the ones, supplied from a pressure network of water consumer.

It follows herefrom, that the reogradient structure of stream can be arranged, applying the following stream forming elements:

- cumulative (linking);
- stream generator (a system of water streams).

A natural transit watercourse can fulfill the functions of the stream forming element. This watercourse washes the working organ at a speed, more than 2,5 times exceeding the carrying away speed of the protected fish.

Transverse circulation of stream allows redistributing of the young fish, falling inside the watercourse into its certain fish withdrawal zone. Flow structure of the stream with transverse circulation can be formed by setting inside the watercourse of a swirling stream forming device. By this, the construction of the last one can be different (swirler with axial and tangential inlet, stream-directive blades, bend, etc).

There are different mechanisms of the young fish redistribution inside the stream. Therefore, characteristics and disposition of the fish transporting zone inside the stream are different (along the axis of water conduit, along its periphery, in certain, for example upper, horizon, etc).

Considering these differences, swirling device can be reasonably classified by a character of the fish transporting zone, formed by it, namely:

- vortical (axial)
- inertial (peripheral)
- rotary-channel (in comfort superficial or in ground layer).

Presence of mechanical, hydraulic or other disturbances in stream could provoke "*phobotaxis*" of fish. This phenomenon could scare fish from the source of danger, in this case it's a water receiving surface of FPS working organ. A structure of stream current, provoking fish "phobotaxis", can be formed by arranging a device of a local or more significant effect in the watercourse which makes fish go out of its impact zone by itself that is of the water intake effect zone as well. Examples of such apparatuses can serve stationary or movable vortex generators, air-and-water veils, etc.

At present the following types of stream forming elements are designed: cumulative, vortex, inertial, streaming, rotary-flowing, air-and-water, air-vesicular and turbulence (Fig. 5.45). Their studies gave a stimulus to create the whole direction in development of FPSs of the stream forming type. As a result, based on these studies, the whole family of reforming fish protection separators was developed.

The working organ of FPS, being a protective-water-receiving element, performs, mainly, water-receiving and distributive function in multicomponent reforming FPS.

The reforming working organ is a surface behind the stream forming element. This surface serves for gradual diffluence of stream into water receiving holes with keeping of optimal hydraulic structure transit current, created at the apparatus inlet. In the most cases, this surface is performed as watertight or as a water conduit wall, and water receiving holes of the consumer are under this surface, frontally to the moving stream inside the device, for example, in fish protection concentrator with vertical separation.

The obstructing working organ is a fine- or a course-perforated surface behind the stream forming element. This surface serves for uniform selection from the transit stream of the working stream by perforation to the water consumer at simultaneous exclusion of the young fish ingress into a water intake. This is not a frontal type of the water intake, but a "slot-type" one. Transit (fish withdrawal) zone is the same for both types of the working organ that is behind the stream forming element. So, arrangement of the obstructing working organ behind the stream forming element (for example, incoming border of threshold) allows giving a new quality to the whole FPS: it becomes the only withdrawal reforming structure at night, mostly using natural features of passive falling of the young fish and withdrawal fish-obstructer in the daytime, orienting the young fish to the active going out of a barrier (protective and water-receiving screen).

The partitioning off working organ represents a watertight screen, installed in a zone of water intake affection. This screen serves to prevent a direct access of the young fish to a consumer from the fish habitable horizons of a basin and to provide water withdrawal from the basin horizons of low inhabited young fish. For effective operation of partitioning off working organ it is necessary to realize the actions for redistribution of the young fish into protection zone (protective screen) and for providing the naturally and artificially arranged transit current along this organ for carrying away and transportation of fish, accumulated in front of this screen, out of the water intake affection zone.

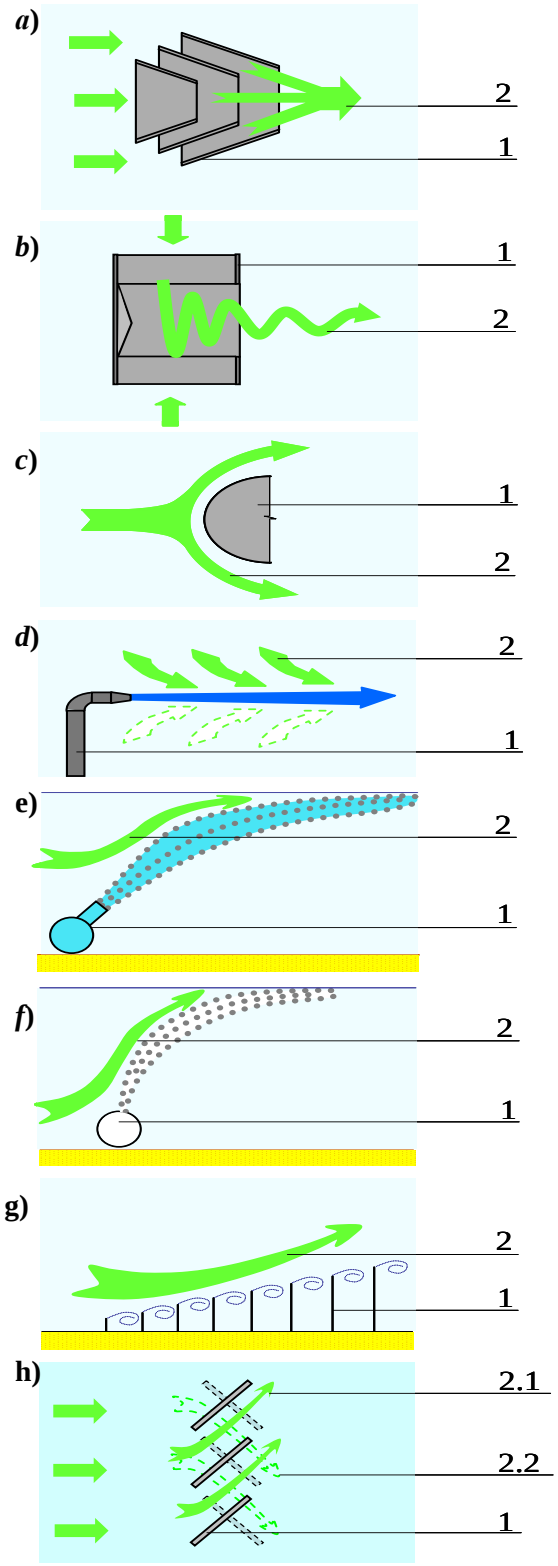


Fig. 5.45. Main types of FPS stream forming elements:
a — cumulative; b — vortical; *c* — inertial; d — streaming; e — air-and-water; f — air-vesicular; *g* — turbulence; *h* — rotary-flowing;
1— stream forming element;
2 — trace of the young fish, falling inside the formed transit stream (*2.1* — in superficial layer; *2.2* — in bottom layer)

For a water consumer the basic characteristics of the working organ are:

• the rated working consumption Q, estimated by water intake productivity;
• through perforation A, mainly, defining a capability of withdrawal and fish-protection apparatus and by this, its technical and operational characteristics;
• possibility of effective operation in conditions of the certain basin (in transit current of watercourse, stagnant reservoir, etc) is also influencing the character and parameters of operational costs that are necessary for effective operation of the whole water intake, particularly, for the protected young fish withdrawal.

Besides the working organs of any construction, FPS is to ensure more than 70 % of the young fish protection effectiveness from ingress into water intakes. (SNiP 2.06.07 – 87) [1].

At classification of the working organs, namely, making its periodical table (Fig.5.46) the above-mentioned characteristics were taken into account. It was made by following:
• a working consumption of the taken water increases with a growth of the line serial number, in which the working organ is placed;
• through perforation of the working organs increases in table left-to-right, changing from null (partitioning off FPS) to one (reforming FPS);
• on top of the table the working organs, operating effectively in conditions of watercourse at speeds exceeding the carrying away speed for the protected fish, are shown, and on bottom of the table the working organs, intended for operation in stagnant reservoir and dead canals, are shown;
• placement of the certain types of the working organs in the exact cell of the table with appropriate rated consumption, ensures the normative, making more than 70 % effectiveness of the young fish protection.

In the first column of the periodical table partitioning off working organs are presented; in the second and third ones fish-tight minelayers, filtering and reticulate, accordingly, are given; in the fourth and fifth columns fish-pervious "minelayers" with large-perforation surface and louvered ones, accordingly, are shown; in the sixth and seventh columns reforming working organs - blank surfaces of diffluence and water conduits "without stuffing", accordingly, are presented.

In the first row of the table headwalls of outlet pipes, installed in the watercourse, having no system of compulsory fish withdrawal, are presented. As they operate at water conduit and intended for the least water consumption, the feature of these headwalls is their streamlining (mainly, a drop-shape form). It results in their compact location at the outlet pipe even provided that the working stream will be supplied through their water receiving surface "inside" the apparatus, i.e., a speed of water inflow will gradually raise. However, parameters of water receiving surface can be increased without essential harm to configuration of headwall at the water intake because of insignificance of the offtaken water and permanent transporting affection of watercourse transit current on the young fish to provide the necessary fish protection effectiveness.

Double-level partitioning off FPS with regulated horizons of water withdrawal and modifications of the streamlined headwalls with "flat" superficial and bottom lower protection surfaces are presented in the second row. The last surfaces provide intake of the working stream inside the apparatus. It is also necessary to mention that such FPSs are intended for larger consumption than devices from the first row. It can be explained by the following:

Periods (lines) of the working organs	Groups (column) of the working organs						
	Partitioning off	Obstructing				Reforming	
	Watertight surfaces	Fish-tight surfaces		Fish-pervious surfaces		Blank surfaces of diffluence	
		Filtering	Reticulate	Large-perforated	Louvered	Bottom border	Water conduit "without stuffing"
	A = 0	0 <A<0,6		0,6<A<1,0		A=1,0	
	1	2	3	4	5	6	7
1 Q<0,5	1	2	3	4	5	6	7
2 Q<5,0	8	9	10	11	12	13	14
3 Q<10,0	15	16	17	18	19	20	21
4 Q<25,0	22	23	24	25	26	27	28
5 Q<50,0	29	30	31	32	33	34	35
6 Q>50,0	36	37	38	39	40	41	42

Fig. 5.46. Periodical table of FPS working organs

- the limiting factor of umbrella-type headwalls application is permanent vertical migration of the young fish depending on weather conditions, season, time of day, etc. That is why at the constant horizon of water withdrawal, ingress into water-receiving hole of the young fish moved to the water-intake horizon can be partly prevented by decrease in a speed of the working stream inflow into the apparatus, i.e. by reducing of the working consumption taken to water consumer. In process of regulating of the withdrawal horizon inside the apparatus, it's possible not to reduce a speed of the working stream inflow inside the device, i.e. significantly increase the water intake productivity;
- arrangement of lower surfaces of the streamlined headwalls in "flat" form allows significantly increasing its area by fixing of the required width (height) of streamlining prismatic headwalls. It provides the intake of necessary (increased) consumption with permissible speeds of the working stream flow.

The third row of the table includes "flat" protective and water-receiving surfaces, ensuring, as the previous ones, an intake of the working stream inside the device. They are sufficiently different in comparison with the previous devices.

Firstly, "flat" surfaces of the third row can be installed at any angle to transit current or inside the watercourse of any configuration, arranging due to these features the necessary hydraulic mode of streamlining by its transit stream for operation of the certain FPS and selection from the transit stream of the working flow with permanent speeds (not increasing as inside devices of the first row).

Secondly, with the exception of the portioning off boom, "flat" surfaces (screens) can be placed both horizontally and vertically, widening by this a zone of their use at water intakes of different configurations.

Thirdly, "flat" surfaces are the particular case of cylindrical surface. In its turn, application of cylindrical surfaces makes a zone of their usage at different water intakes more wide.

Fourthly, a system of compulsory fish withdrawal can be connected to the working organs of the third row that would allow their application at almost all the basins.

Constructions of the working organs of the first two rows imply, mainly, an operation of water intake at watercourse, i.e. without using a compulsory system of fish withdrawal. Working organs of the third row are in the intermediate position, i.e. they can operate, using the natural current and artificially created fish withdrawal. Working organs of the following rows are intended for work with the system of compulsory fish withdrawal.

So, the fourth row contains partitioning off FPS, equipped with fish withdrawal tray and placed independently, for example, at water-intake holes of water-receiver or inside cylindrical watercourse there are conic surfaces with coaxial headwall of fish withdrawal.

Difference of water-receiving cones and of the diffuser from the similar working organs of previous rows consists in that the supplying of the working stream from them into a water intake is realized "outside", as a result of this, they acquire a significant advantage.

This advantage consists in the following. A hydraulic structure of water stream, entering the device, is arranged by a stream forming element in such a way that along the device axis the increased-speed current is created, transporting the young fish into the headwall of fish withdrawal. Working stream is redistributed to a periphery of the device (into water intake) with constantly reducing centrifugal speeds that do not sufficiently affect the young fish, falling along the axis. So, a process of the young fish protection starts long before its possible contact to water-receiving surface. This allows using the compact enough devices for water withdrawal with large consumption.

In the fifth row of the table there are many working organs. Performing them as composed devices, provides a possibility of more gradual distribution of the incoming stream into water intake and at the same time it allows reducing the possible spontaneous contact of the young fish to water-receiving surfaces. This allows using of the composed working organs for intake of more working consumptions, than by the third row devices.

The sixth row contains the working organs, intended for intake of the largest consumptions, therefore, definite restrictions are set for these organ constructions. For example, restrictions, connected with configuration features of water intakes allocation in power canals. A width of these canals does not significantly exceed its depth, that predetermines a vertical disposition of protective and water-receiving screens.

For providing an effective work of the sixth row apparatus, a system of compulsory fish withdrawal is so much important that a device of "Artificial bar" type is placed inside the "Partitioning off working organs". This device consists of autonomous stream generators, which create a fish transporting speed from the water intake. These generators are placed in a zone of the falling young fish accumulation before the water intake (for example, in the superficial layer of the hydraulic power plant waterfront). It gives the grounds to consider that the present working (transporting) organ also fulfills the functions of stream forming and fish withdrawal elements.

Filtering water receiving part of the working organ is represented here by an extensive laminated concave side of watercourse bend that is naturally washed by the spilling current, formed by a transverse circulation of watercourse in this zone.

Fish withdrawal element of FPS (fish withdrawal) is intended for withdrawal of the protected viable young fish out of FPS working organ coverage into a safe place of fish habitable water source for its following natural reproduction.

Basic functional indicators of fish withdrawal operation are its transporting ability, characterized by the stream current speed that carries out the young fish from the water intake affection zone, as well as consumption of fish withdrawal in accordance with the working consumption of water, taken by the water consumer.

Fish withdrawal (a system of the young fish withdrawal from the water intake affection zone into a safe place of a water source) is reasonable to consider depending on use of a watercourse character for this current, namely:

- as a natural current of watercourse;
- as artificially arranged current of watercourse;
- as a current inside deferent tracks (conduits, canals, etc.).

By this, the natural current of watercourse can occur inside *the river bed* and also inside *the artificial canal.*

Artificially arranged current for withdrawal of the young fish from the water intake, can be set up by creation of a man-made bar or a local hydraulic screen.

Man-made bar is designed with a help of the system of logically installed autonomous stream generators. These generators are installed inside the faintly running basin for withdrawal of the young fish, protected inside the fish protection separator in case when creation of fish withdrawal

track is not possible or non-value-added. In its turn, this system of stream generators forms a local current (stream) from the working organ into a safe place of the basin, i.e. outside the zone of the water intake affection.

Hydraulic screen solves the more local task, namely, withdrawal of the protected young fish from the working organ coverage, for example, louver screen. In this case hydraulic screen performs a function of not only fish withdrawal element, but also the stream forming and working ones.

Withdrawal of the protected young fish from the water intake coverage inside the fish withdrawal tracks is the most widespread method of fish withdrawal arrangement, practically, at any water intake, placed inside the faintly running basin. Transportation of the young fish can be realized:

- by conduit;
- in open or closed canal;
- in specially arranged area in water-supplying canal of water surface.

Compact conduits are reasonable to be laid from fish protecting separator backwards to water source at the bottom of short water intake scoops or canals.

At presence of more extensive canals, significant power resources are to be used for creation of the current inside the conduits that is not economically expedient. So, in this case it is more reasonable to arrange a *special water area* inside a water supplying canal, screened from the water intake, for example, by a longitudinal wall. By this, in water territory a special current is not created, except the water current, supplied from the headwall of fish withdrawal. It is reasonable to apply *closed* or *open canals* in case of setting of fish protecting separators at the significant distance from the water source. A choice of the canal type depends on topographical characteristics of the area. Besides, the closed canal is a connecting section between the headwall of fish withdrawal and the open canal. In dependence on topographical characteristic of the area (sharp inclinations of the ground surface, differentia between reaches of hydro system, etc.) the current can be free-flow in fish withdrawal tracks. In case of their absence, the current is arranged in fish withdrawal tracks by special devices (ejectors, water-vanes, etc.). In this case fish withdrawal consists of the following elements: headwall of fish withdrawal, current creation unit, fish withdrawal track (conduit, canal, etc.).

The main types of fish withdrawal are shown in Fig.5.47.

An auxiliary element of FPS is intended for increase in protection efficiency, essentially, of the grown-up, floating fish inside the basin by implementation of additional fish protection measures, allowing more complete and more effective using of "fish-protective" properties of the basic functional elements, as a whole, and separately. By this, one or several auxiliary elements can be included in construction of FPS. As a rule, auxiliary elements make a physiological impact of different origin on fish. This impact provides independent active movement of fish into local zones with more comfortable conditions of habitation, being simultaneously removed from the zone of water intake affection.

Depending on a way of impact on the protected fish, auxiliary elements are divided into three main groups:

- orienting (directive);
- attractive (arresting);
- repellent (repugnatorial).

Orienting auxiliary elements are intended for:

- limitation of a zone of safe falling of fish along the working organ (air-bubble screen, tactile orientator, electric fish rejector, and "light path") that reduces a possible contact of fish to water receiving surface of FPS working organ, its possible harm and death. As a result, a fish protecting efficiency of the whole device increases;
- improvement of conditions of fish withdrawal from the water intake affection zone (tactile orientator, "light path").

As a result of application of the orientating auxiliary element in a system of fish withdrawal of FPS, it is succeeded considerably to reduce a length of fish withdrawal tracks and to reduce power inputs for creation the water currents in them.

In most cases for creation of *air-and-water screen* (AWS) by the perforated headwall of an air duct – *airlift*, the stream forming element of FPS is additionally set. By this, the trail of AWS is placed along the border between the transit current, transporting the protected fish into fish withdrawal, and a zone of stream diffluence along the working organ of FPS. Being a visual and an acoustic barrier for the majority of actively moving fish inside the stream, AWS prevents the withdrawal of fish from the zone of stream into FPS working organ coverage. It provides a contactless protection of both the falling young fish, persistently washed away inside the stream, as well as the grown-up fish, ready for more independent movement inside the water course.

Tactile orientator (longitudinal trays, partitions, etc.) is arranged in the peripheral zone of FPS working organ, washed by the transit current. It is intended for providing the possibility for the grown-up fish to restore its tactile orientation and independently withdraw from the "high-speed" zone of the transit current, not flowing, by this, to the water receiving surface of FPS working organ for a rest, for the following fall in the zones with the lowered speeds of current or steady tactile orientation.

Electric fish rejector is a system of electrodes, creating fish repugnatorial electrical field. This field is intended for stimulation of fish leaving the water receiving zone of FPS working organ into transit peripheral zone with the following fall inside this zone into a headwall of fish withdrawal. As a rule, electric fish rejector is placed in parallel or at an angle to the water receiving surface of FPS working organ. In some cases this rejector can be a water receiving surface itself.

"Light path" is intended for restoring of fish orientation in the stream or for stimulating of its movement in the required direction for fish protection purposes. Depending on a purpose "light path" can be arranged both in the water receiving zone and in transit zone of FPS working organ. It can be moving, that is, "progressive wave", created by alternate switching-on of electrical lamp lines, and can be stationary, implemented by the constantly lightening lamps or black and white marking, namely, "zebra".

Appellant auxiliary elements are intended for:

- attracting and keeping the migration fish in safe and distant areas of water source from a zone of water intake affection (for example, aerator, places of optimal habitation, hazard beacon and sound call). It allows decelerating for a long time or stopping at all the falling of fish in the water intake coverage zone. In this connection, application of appellant auxiliary elements can be considered in most cases as the independent fish protecting measures and as an alternative to equipment of water intakes by fish protecting constructions;
- attracting and stimulating the fish movement at FPS into the headwall of fish withdrawal (hazard beacon and sound call);

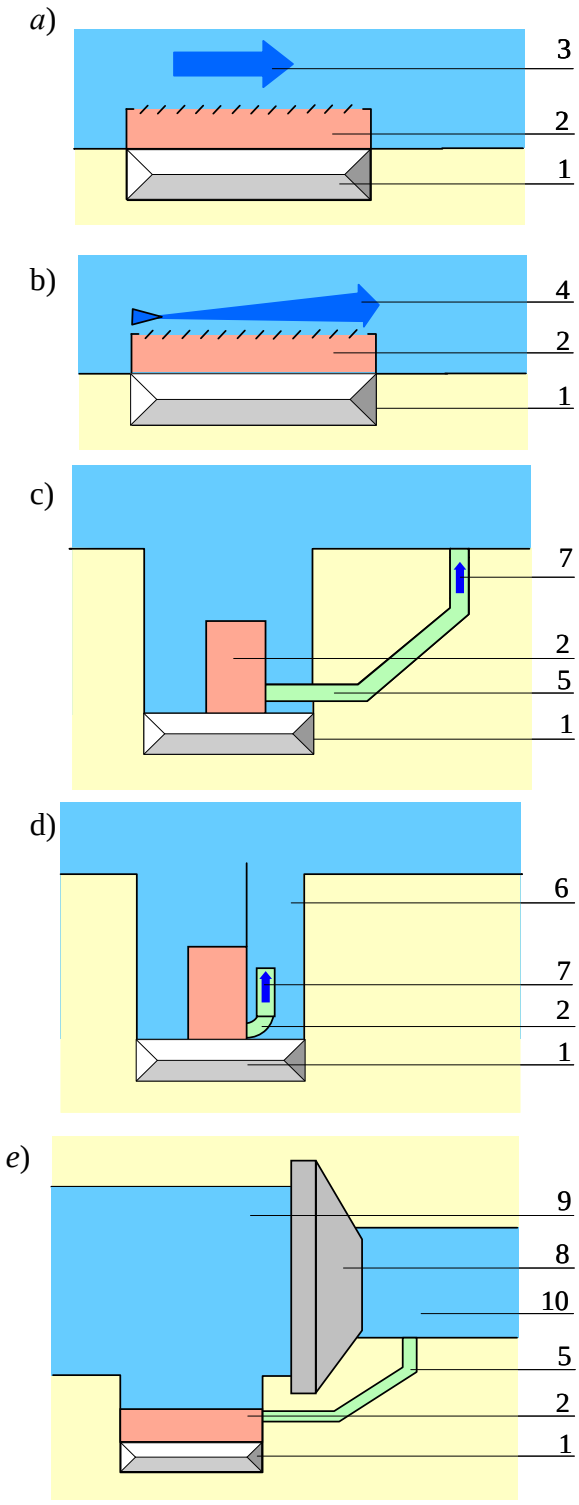


Fig. 5.47. Basic types of FPS fish tapping elements:
a — natural current of water stream; artificially organized current; b — inside the basin; c — in fish tapping track; d — in specially partitioned off area of water; e — free-flow current;
1 — water intake; *2* — fish-protection device; *3* — water stream; *4* — hydraulic screen; *5* — fish tapping track; *6* — fish tapping area of water; *7* —unit of current creation in fish tapper; *8* — dike; *9* — forebay; *10* — downstream.

- reduction of fish withdrawal tracks length and electric consumption for arrangement of the water current inside them (aerator, places of optimal habitation, hazard beacon and sound call).

Aerator is reasonable to be used in basin with low content of oxygen in water. In this case at setting the aeration installations of different types (flowing and stationary aerators, perforated pipelines connected with pressure air duct, etc.) in distant from water intakes areas of intake basin, an independently move of the fish herd and the nutritive base of a basin from the water intake affecting zone into the aerator affecting zone, can be achieved. By this, it is reasonable to apply mobile flowing aeration installations that allow more promptly reacting to the changing hydrological, air-and-water and hydrochemical situation inside the basin and concentrating the fish in optimal in the present moment areas of a basin. Aerator can be placed also in long fish withdrawal tracks of FPS for improvement of an oxygen mode of the current, created in them, and at the inlet headwall of fish withdrawal for attracting to it of the protected fish.

Places of fish optimal habitation are areas of basin with optimal bottom shape, hydrological, temperature, oxygen and nutritional modes for fish habitation. And they are intended for improvement of habitation conditions and fish fattening and also for delaying and full stopping of falling of the young fish of early age groups down the current in dangerous zone, for example, to water intake constructions.

Places of optimal fish habitation are divided into the following:

- *riverbed* places intended for delaying of the young fish falling from spawning areas. They are located in the streamflow straight down the current of spawning areas and up the dangerous zone (water intake). Local stationary and moving riverbed places of optimal fish habitation can be additionally set by inlet headwall of fish withdrawal for the purposes of decrease in the length of FPS fish withdrawal tracks;
- *riverside snare and fish-storage devices*, located in natural and artificial bays and intended for a delay of the young fish falling from spawning areas and, mainly, prevention of the young fish ingress into water intake and spillway constructions by keeping of fish in comfortable conditions of habitation. There can be also directed the fish withdrawal tracks of FPS.

Places of optimal fish habitation can be considered as independent fish protection constructions, especially, in cases when it is necessary to delay or fully stop the fish falling into spillway constructions of large hydroscheme or water intake of hydropower station. In this connection, they consist of the whole complex of basic functional elements and are equipped with the incoming stream and fish-directive headwalls, with the working fish-accumulative area of water and by the system of keeping fish in the area of water (hydraulic, mechanic, relief, etc.), i.e. opposite to fish withdrawal. Incoming headwall of places of optimal fish habitation is reasonably equipped with auxiliary fish directive device.

Light and sound calls are reasonable to use in fisheries for redistribution of fish in the water intake coverage zones or spillway coverage, being distant from them, nutritional zones of basin. Calls can be of different constructions, provided that their signal is well perceived by fish and is well given during its nutrition periods. Calls can be also placed in the headwall of fish withdrawal for orientation and attraction into it of the protected fish at the safe areas of the basin, located behind the outlet headwall, as a rule, of the shortened fish withdrawal for arranging the independent movement of fish along the planned track of fish withdrawal.

Repellent auxiliary elements are intended for scaring the fish from water-receiving zones of FPS working organ to prevent the fish ingress into water intake.

In most cases in FPSs they are constructively and functionally similar to the orientating auxiliary organs. But at some conditions (small productivity of water intake, little damage, made by them to the fishery, etc.) repellent auxiliary elements can be possibly applied as independent fish-protecting constructions.

Air-and-water screen (pneumatic barrier) is situated before the water intake inside the indifferent zone of its affection, i.e. in the places, where the speeds of water current in the water intake do not exceed the threshold speed of protected fish flowing. Presence of a transit current of water course along AWS is rather desirable. Constructively and functionally the repellent AWS is similar to the orientating AWS. Its operating principle consists in scaring fish, contacting the visually impenetrable moving "partition". Besides, since the repellent AWS is located in a zone of low speeds of water current, its flare rises practically vertical up. By this, along the flare ascending water current is formed, and it carries along the young fish. Spreading along the surface, it promotes carrying-out of fish in the superficial layer from water intake backwards to the basin that can be considered as a display of fish withdrawal functions. But the most reasonable is a joint operation of AWS with protection and water-receiving surface of the working organ of another type, for example, a reforming one, with direction of the air-water flare adjacently to the transit current into a headwall of fish withdrawal, i.e. application of AWS as the orientating auxiliary element of FPS.

Light and sound barriers are systems of pulsing lamps, hydrophones, sound vibrators, etc., which are installed in the indifferent zone of water intake affection and serve for additional equipping the FPS working organs, and intended for affecting fish in deterring-orientating way that prevents its coming into a dangerous zone.

A block-diagram of reforming FPS combination and possible its completing with auxiliary elements is shown in Fig. 5.44.

An algorithm of optimal FPS construction for the certain object

Typical features of FPS components of basic functional (stream forming, working and fish withdrawal) as well as auxiliary elements were considered above. During creation of optimal constructions of FPS for the certain object, it is necessary to plan the basic ways of selection of each functional element type. Selection of functional elements type is affected by the following factors:

- *ichthyological situation*, occurring inside the basin in water intake coverage (length-specific composition of fish, which needs to be protected, a character of its falling, nutritional and migrations, etc.) and affecting the stream forming element and, mainly, the working organ;
- *Topographic*, *hydrological*, *climatic* and other elements of situation, affecting all three functional elements of FPS;
- *Capital and operational costs*, affecting all three functional elements and, mainly, the working organ and fish withdrawal;
- Ensuring the required *fish-protecting efficiency*, affecting all three functional elements of FPS and, mainly, the stream forming element;
- Providing *withdrawal* of the protected young fish in viable condition in safe place of fish habitable water source, affecting fish withdrawal.

Taking into account the considered above, it is necessary to mention, that at development of FPS construction, i.e. the optimal one for conditions of the certain water intake, a problem solution algorithm can be composed as it is shown in Fig. 5.48. At the first stage, the object (basin and water intake, placed on it) is inspected. In parallel with it, the analysis of present constructions of functional elements is carried out, their types are selected, being the most suitable for the certain conditions of the considered object. A complex of basic inspections and investigations, required for a complete design of fish protection kit, consisting of the examined and selected types of functional elements, is determined

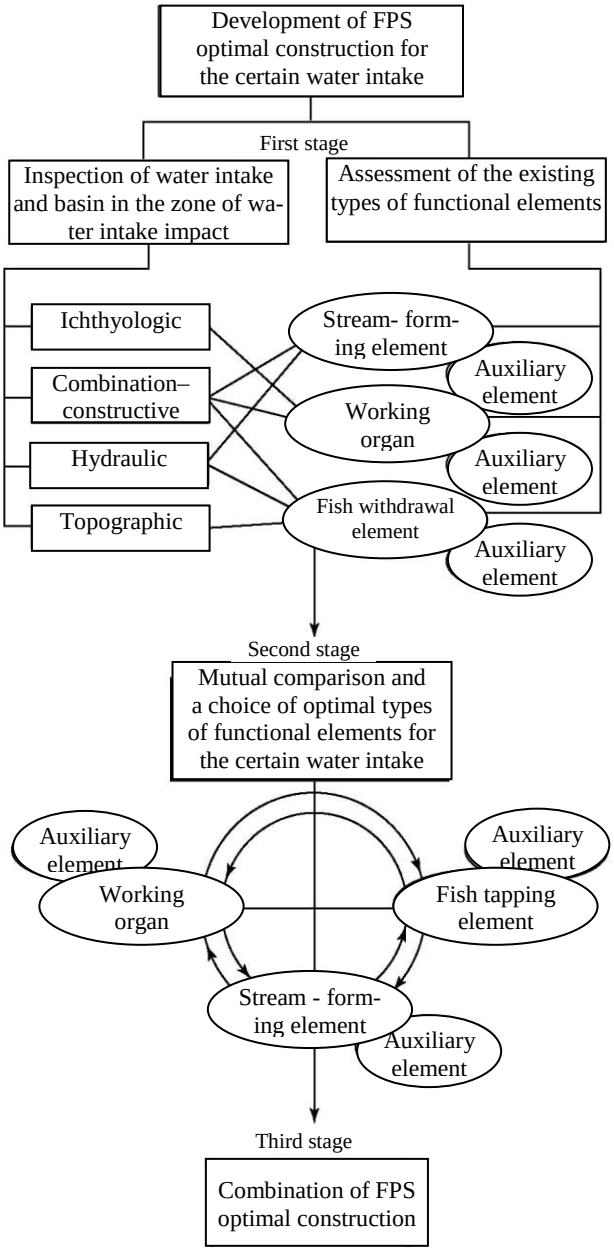


Fig. 5.48. Algorithm of optimal construction of FPS selection for concrete object

Parallel implementation of exploratory and preproject developments allows the following:

- Firstly, to save money, refusing from conduction of investigations and researches in corpore and from gaining by this of significant body of the object information, which is not claimed during the real projecting;
- Secondly, to focus on forces and means for solution of the really required problems, occurring at development of FPS for the certain object, that consists of functional elements, being the most suitable to the present conditions.

At the second stage, based in the gained results of investigations and researches, a joint comparison of functional elements, selected for the further design, is made. Its result should be a choice of the complex of optimal for the certain conditions as well as for mutually connected types of each out of three basic functional and auxiliary elements, included in FPS, optimal for the certain water intake, arranged inside the concrete basin.

At the third stage, the immediate constructing of FPS is started:

- compiling the construction out of three basic functional elements;
- its completion by auxiliary elements, if required;
- arranging the fish protection complex in the water intake with its equipping with additional elements (connecting and transfer devices, different mechanisms, etc.)

A method of FPS optimal construction selection is realized in more than 30 projects of fish protection constructions for such objects as water intakes of Sevanskaya hydro power station on the lake Sevan, Cherepovetskaya SDPP on the river Sud, Konakovskaya and Nizhegorodskay SDPPs on the river Volga, Kundankula nuclear power plant in the Indian ocean, Kalininskaya CHPP-3 on the river Tverc, Kumertauskaya CHPP and CHPP of "Salavatnefteorgsintez" on the river Belaya, as well as at CHPP of Shalinskaya irrigation system on the river Argun, Chrunichev space-rocket centre on the river Moscow, Zavolzhskiy motor plant on the lake Michalevo, etc.

Novelty of the method consists in realization of three-stage scheme of fish protection with compulsory application of the incoming stream forming element in structure of FPS, providing contactless, i.e. not injuring, protection of the young fish and being a dominating constructively and hydraulically forming element of the whole device. Realization of the method is possible at diversion facilities of different purposes, located at any fish habitable basin and water course.