HEAT PUMPS INSTALLATION FOR HEATING-COOLING THE WATER FROM RE-CIRCULATING AQUATIC SYSTEMS

INSTALAȚIE CU POMPE DE CĂLDURĂ PENTRU ÎNCĂLZIREA/RĂCIREA APEI DIN SISTEMELE ACVACOLE RECIRCULANTE

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***Abstract**: The efficiency of aquaculture practiced in recirculation system types depends by more than one factor, among which the most important is the energetic consumption of the system. To assure a high grade of energy conservation in an aquatic recirculation system, it must be maximized the water recirculation grade and impose the utilization of some unconventional energy sources for heating, respective cooling the water. For this purpose the optimum solution is using an installation for heating/cooling the water with heat pumps.*

***Rezumat:** Eficiența acvaculturii, practicată în sistemele cu recirculare, depinde de mai mulți factori, printre care cel mai important este energia consumată de sistem. Pentru a asigura un grad de conservare al energiei ridicat, într-un sistem acvacol recirculant, trebuie maximizat gradul de recirculare al apei şi trebuie impusă folosirea unor surse de energie alternative neconvenționale pentru încălzirea, respectiv răcirea apei. Pentru acest scop, soluția optimă este folosirea unei instalații de încălzire/răcire a apei cu pompe de căldură.*

***Key words:** system, aquatic, recirculation, super intensive, heating, cooling, heat pumps.*
***Cuvinte cheie:** sistem, acvacol, recirculare, superintensiv, încălzire, răcire, pompe de căldură*

CONSIDERATION REGARDING AQUATIC RECIRCULATION SYSTEMS FOR FISH SUPER-INTENSIVE BREEDING

Aquaculture is the field which recorded the fastest evolution on world plan, from all agriculture fields, this activity sector provides approximately 20% of the consumable aquatic products. Currently, intense researches are done for establish the most adequate intensive systems and technologies for breeding high valuable species from the family of acipenseridae, salmonoids, siluridae, etc., with the purpose to achieve a high competitively level on the world market and to realize a real protection of the natural reserves. In Romania, fish breeding as a field of aquaculture, is still tributary to extensive or semi-intensive breeding system, using large surfaces and amounts of water for realization of one fish unit and it is orientated on producing piscicultural material from the ciprindae east-Asian species, species which are not liked on the European Community market and in a high proportion on the national market. SWOT analysis made by the Central public authority for Fishing and Aquaculture from Romania revealed the opportunity of introduction intensive and super-intensive breeding systems and technologies which can assure large productions for the surface and volume unit as well as enlargement of the valuable species type which can make the breeding object in Romania.

Fish breeders orientation for a super-intensive recirculation system (SAR) it's a sequel of the fact that this system offers advantages toward breeding fishes in ponds, like:

- saves the terrain and water resources;

- can be placed in places which are improper for breeding in pond;
- allow a high control grade of the fish breeding environment;
- fish can be bred during whole year;
- fish can be harvest at the desired moment;
- fish production is much higher reporting to the water volume used;
- fish production and the level of income from valorisation of these can be determined more accurately than in ponds.

Because of this advantage, interest for recirculation aquatic systems for fish production is in continuous growing, despite the lack of technical and economical information in this field.

A recirculation aquatic system (SAR) for super-intensive fish breeding it's a partially closed system, which allows the breeding of fish in controlled environment conditions by water treatment and recirculation. Water treatment from the system consists in removing the residuals solids, ammonia and nitrite oxidation, carbon dioxide elimination, oxygenation and aeration and in some cases water disinfection. In Figure 1 the technological scheme of a super-intensive fish breeding SAR is represented. Main technological equipments used for water treatment are: mechanical filter, biological filter, aeration or oxygenation devices and UV filters. For creation of the optimal environment conditions for fish breeding it's absolute necessarily to assure a adequate quality of the recirculation water.

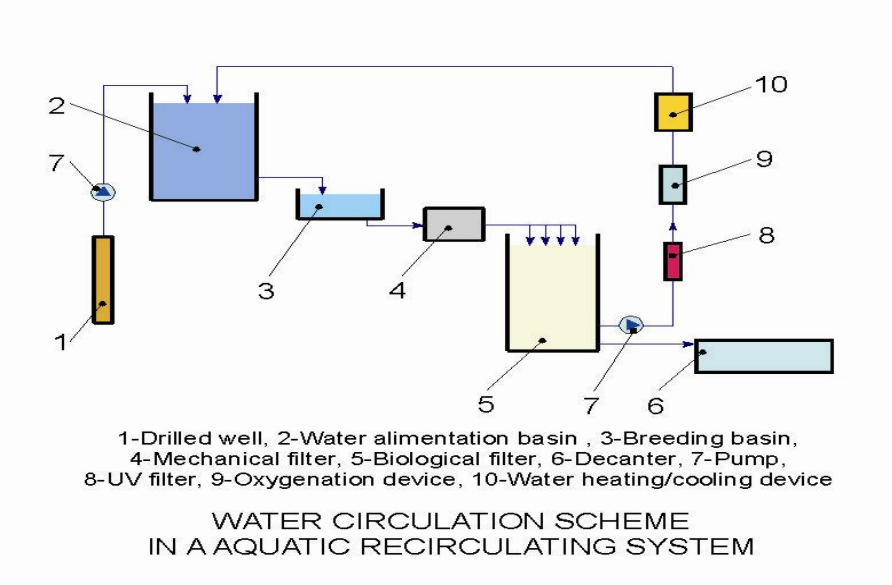


Figure 1

TECHNOLOGICAL AND ECONOMICAL CONSIDERATIONS

Efficiency of the aquaculture made in the recirculation systems type depends of many factors, the most important is the energetic consumption of the system.

To assure a high level of energy conservation in a recirculation system must be established the optimum report between the water intensity recirculation (recirculation debit) and the replacing rate of water (renew debit). Water recirculation intensity is determined, firstly, by the dynamic of ammonia production of the culture biomass and the renew rate it's

imposed by the condition of keeping the nitrate concentration from the breeding water in the optimum area. Recirculation intensity, respectively water renewal, affects in a decisive way the energetic balance of a breeding system. So, if the recirculation of water keeps the energy in the system, water renewing is the main factor of losing energy from the system. That's why, energy conservation criterion in a recirculation system impose a high as possible level of water recirculation and a renewing rate as low as possible.

In the condition in which the energy consumption for increasing temperature with a 1^oC of a $1m^3$ of water is 1.16 kWh, the energy required to circulate the same amount, considering a pumping height of $H_T = 10$ mcA, it's about 0.045 kWh, so 25 times smaller. It is obvious the fact that water recirculation will be preferred until the allowed limit by the efficiency of filtrating systems, disinfection and oxygenation. In this way, is illustrating the example of two breeding systems, similarly regarding the capacity, respectively the difference between the renewing water and the breeding water, but different, regarding the recirculation rate, realize different levels of electrical energy consumption for water heating. So, a system with 97% daily recirculation level and the renewing at 3%, consume about four times less energy than a system with a recirculation of breeding water lower than 90%, and the renewing of water is more than 10%.

Lowering the costs of the electrical energy consumption needed for the system to work at acceptable levels, impose the satisfaction of the next technological requirements: maximization of the water recirculation level, assure a efficiency thermo isolation of the technologic environment for keeping an optimal temperature in the breeding basins, and the most important aspect, utilization of some alternative unconventional energy sources for heating, respectively cooling the water.

TEMPERATURE INFLUENCE UPON THE WATER QUALITY AND FISH HEALTH

For fishes – animals with variable body temperature, water temperature is one of the main factors for surviving. Every breed has own boundaries and conforming to this breeds group on particular sectors in the flowing water or at a particular depth in seas and lakes. When these boundaries are breached for a long time, not mattering if is under or below the superior and inferior limits fishes suffer because of metabolic deficiency. Especially high temperature variations unleash great death rates.

When it passes suddenly from one temperature to another (3-5º C differences), fishes or spawn die in minutes or seconds, because of the shock. In this case, death comes because of the musculature paralyze of the brachial system and heart and so the blood circulation can be made no more. This phenomenon is quite frequent, for example at re-growth , when the temperature homogenization is not preliminary made.

Thermal agent has upon fishes, not only a direct action, but also an indirect one. So, for example, quantity of dissolved oxygen in the water it's reversed proportional with temperature. During the summer and especially than when low barometric pressures are recorded, a great amount of the dissolved oxygen is relieved in the atmosphere. Hypoxia effect on fish is increased because at high temperatures, their metabolism increase and high oxygen quantities are required.

Fishes are systems with variable body temperature, their temperature being equal with 0.5-1º C lower or higher than the water they live in. The intensity of their metabolism is dependent on this medial factor. For warm water fishes, a high temperature means a high metabolic rate. For cool water fishes, the metabolism continues at lower temperatures, but at high temperatures, upon 20º C, the metabolic rate decreases.

Water temperature has a great influence upon fish breeding as well as his sanitary condition. Immune system, for most fish breeds, function well at a water temperature around 15º C. Water temperature impact upon health condition of the fishes is in the same time direct and indirect and it is felt, every time when this parameter is outside the optimal area of each breed.

Optimal thermal area it's a general notion because it differs for the same breed reporting to different physiological moments. So, at the rainbow trout, optimal thermal area for breeding is between 10-18º C, and the optimal temperature for embryogenesis is between 5-10º C.

Water temperature has a direct effect upon fish breeding and their fertility, respectively upon the breed genesis, semen genesis and embryogenesis. Any deviation from the optimal thermal area influences in negative ways the physiological processes.

For fishes, to low or to high temperatures are harmful, but more dangerous are sudden oscillations (especially sudden decrease of temperature), which has the effect of thermal shock production (variations higher or equal with 7º C), generator of a stress reaction, with energetically and immunological consequences.

In the gradual and small thermal oscillation case the fish have the capability to modify their enzymatic equipment and to produce iso-enzymes which can activate in concordance with the environment temperature.

Sudden temperature oscillations doesn't allow enough time for the fish to produce the needed iso-enzymes, it cannot adapt and enters in thermal shock condition, characterized through brachial and heart musculature paralyze, through serious disorders of the entire organism, followed by death.

Direct impact, lethal, leads to coma and death of the fish, preceded by a sudden anorexia, an excitation phases accompanied by breath acceleration and frequently defecations, followed by lost of equilibrium, hypo-dynamic, congestion or paleness of the gill, matte colour of the body. Too high temperature also influences directly the fish condition, causing some metabolic disorders, externalized through anorexia, asphyxiation, and grow stooping.

The reasons shown above prove the importance of the keeping a constant water temperature in a SAR.

WATER FROM A SAR HEATING AND COOLING METHODS

Generally for heating and cooling the water from SAR different technologies are used.

For debits relatively small ($1 \div 2$ m^3/h), for water heating are used electrical equipments (heaters with electrical resistance) rigged up on the alimentation pipes of the basins. For higher debits are used heat exchangers with primary agent (heating agent), hot water obtained from a electrical boiler or a hot water boiler with solid, liquid or gas combustible. For very high debits are used heat exchangers batteries made by several units, bind in parallel.

For cooling the water in SAR are used usual cooling aggregates with refrigerating agent compression.

Heat pumps – as systems for energy conversion – are thermal machineries which can raise the energy quantity of a system from a low level temperature level to a high temperature level ($50 \div 80$ ^0C). Heat pumps with vapour compression function by the reversed Carnot cycle. Function mode it is similar with the one of a refrigerating installation. They extract the caloric energy from the environment, surface waters, ground waters, land or even air and transfer it to the system which has to be heat. Energetic efficiency of a heat pump, named real performance coefficient, (COP), is defined by the ratio of the produced thermal

energy and the consumed electrical energy for producing this. COP value depends on the temperature difference between cold source and thermal agent; to realize a maximum efficiency, the difference between cold source (water, air, land) and thermal agent must be as low as possible.

Natural sources as air, land, groundwater's temperature vary in accordance with the annual variation of the temperature with a attenuation and a out phasing higher or lower. This means that when the heat necessary is maximal we have the lowest heat available from the natural resources.

So the natural sources which depend little on the exterior temperature are most indicated to be used as primary energy sources for heat pumps installations. These are groundwater and land heat.

Mainly heat pumps types currently used, according to the cold source nature are this: air – water, water – water and land – water.

Doing a comparative analyze of different heat pumps, according to the energy source nature, we obtain the data from the table 1

Table 1

Type/Characteristic	Air – Water	Water – Water	Land – Water
COP value	small	big	big
COP variation according to the climate conditions	Variable	Constant	Relatively constant
Assembly costs	small	Big	Very big
Functioning safety	Small	Big	Big
Thermal power	Small	Very big	Big
Passive cooling possibility	No	Yes	Only for models with vertical well

It can easily be observed that air – water heat pumps have all performance parameters inferiors comparative with the other types. Only from the assembly costs point of view this equipments are better. Water – water and land – water heat pumps have almost all the performance index closed together, with the observation that the ones land – water requires very high assembly costs, which exceed by a lot the costs for two water drilling wells.

Because the water heating/cooling installation must function within a SAR, which obligatory need one or more water wells, it is advantageous from all points of view that for this type of equipment the water –water heat pump type must be used, which has all the advantages shown above. It will be unnecessary the set-up of vertical well or horizontal traps, absolutely necessary for a land – water heat pump to function. This will mean supplementary expense, unjustified.

Using a air –water heat pump is not wanted, mainly because of the small thermal power, which do not satisfy the energetic needs for heating/cooling a recirculation aquatic system and also because of the low energetic efficiency. (COP and EER – cooling energetic efficiency are small).

In conclusion, for the realization of heating/cooling installation of water from a SAR, the optimal solution is the use of water – water heat pump with all advantages shown.

Functioning of the water heating/cooling installation from a SAR with water – water heat pump it is represented in the Figure 2

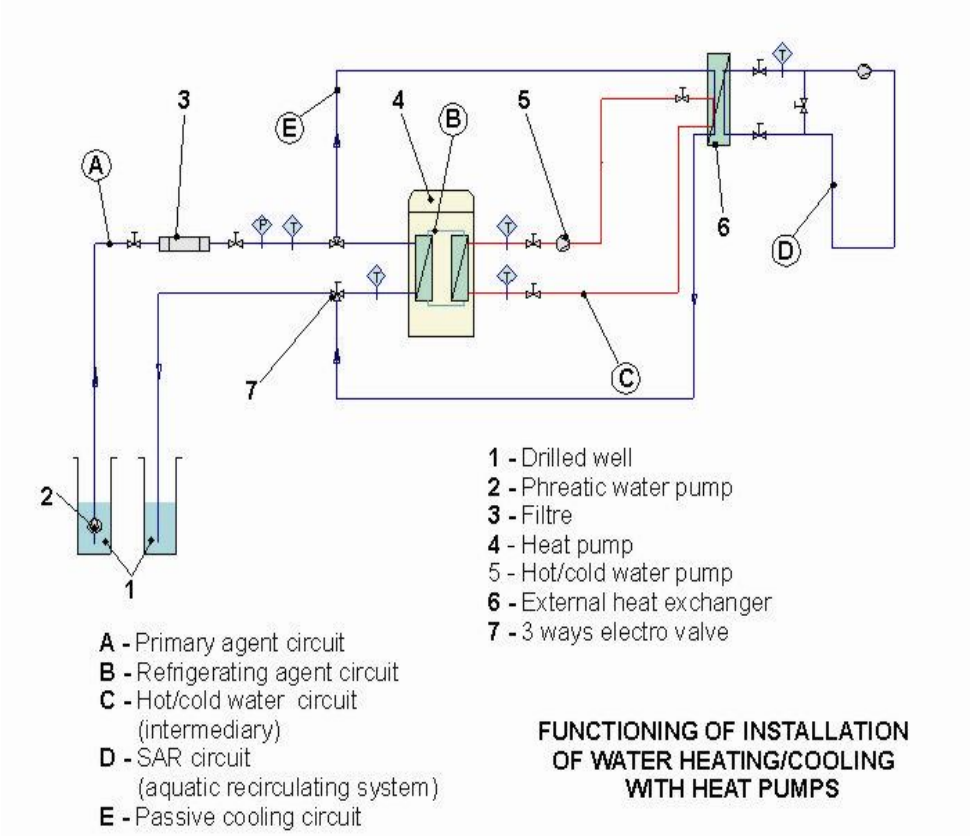


Figure 2

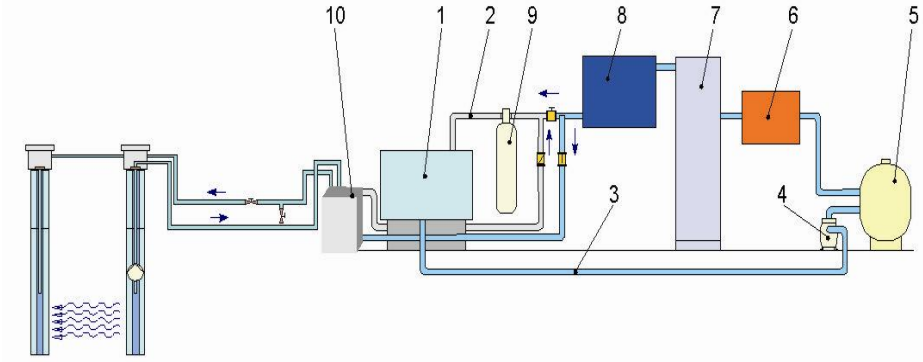
The installation is made by five different circuits: A – primary circuit of the groundwater extracted from the well, (cold source), B – refrigerating agent circuit, C – hot or cold water intermediary circuit, D – passive cooling circuit and E – aquatic recirculation system ASR.

For the realization of heating process, the groundwater extracted from the well (1), with the help of submersible pump (2), goes in the heat pump vaporizer (4), where it give up heat to refrigerating agent, which vaporize. Groundwater, which initially has the temperature of $8 \div 10^0$C, passing through the vaporizer cools down with approximately 5^0C, decreasing to $3 \div 5^0$C. This water it is conduct in the second well (drain well). Refrigerating agent, which has the boiling temperature of -2^0C takes the heat gave up by the groundwater and transforms into vapours. The vapours are compressed in the compressor, and their temperature increase at $+73.5\ ^0$C, after they go in the condenser, where by condensing they give up heat (vaporization latent heat) to water from the intermediary circuit. The refrigerating agent becomes liquid again and the cycle continues. The water from the intermediary circuit, heated up at 65-68^{0}C is

conducted in the external heat exchanger (6), where it gave up heat to the recirculation water from the fish breeding basins.

The cooling process it is been realized in a similar way, only just the water circuits are inverted in the heat pump. The water from the secondary circuit goes to the vaporizer where it gives up heat to the refrigerating agent that vaporizes, and the groundwater absorbs heat from the refrigerating agent in the condenser. This process of water cooling it is used only in exceptional cases (at very high external temperatures). Usually it is used so called passive cooling which consists in the introduction of groundwater directly in the external heat exchanger by by-passing the heat pump. In this way the recirculation water from the basins give up heat directly to groundwater. This functioning regime is very advantageous because the only electrical energy used is the one for the submersible pump.

Technological scheme of SAR with installation for water heating/cooling with water –water heat pump it is represented in Figure 3.



1-Breeding basin, 2-Water alimentation network, 3-Water evacuation network, 4-Pump, 5-Mechanical filter, 6-UV filter, 7-Biological filter, 8-Water basin, 9-Oxygenation device, 10-Heat pump

SUPER INTENSIVE AQUATIC RECIRCULATING SYSTEM WITH WATER-WATER TYPE HEAT PUMP

Figure 3

5. CONCLUSIONS

Fish breeding technology in aquatic recirculation system it's a technology that use great amount of energy. The highest percentage from the production costs it is represented by the expenses with the consumed energy for heating, respectively cooling the water from the basins. That's way the use of solutions with high efficiency for producing the needed thermal energy it's imposed. The most efficient method for heating and cooling the water from a SAR for fish super-intensive breeding it's the use of heat pumps.

This equipment extracts the caloric energy needed for heating a fluid (air, water) from the environment. Comparing different heat pump types, according to the nature of used energy source, we observed that air – water heat pumps have all performance parameters inferiors, comparative with the other types. Only from the assembly costs point of view this equipments are better. Water – water and land – water heat pumps have almost all the performance index closed together, with the observation that the ones land – water requires very high assembly costs.

Because the water heating/cooling installation must function within a SAR, which obligatory need one or more water wells, it is advantageous from all points of view that for this type of equipment the water –water heat pump type must be used, which has all the advantages shown above. It will be unnecessary the set-up of vertical well or horizontal traps, absolutely necessary for a land – water heat pump to function this will mean supplementary expense, unjustified. At the same time, by using a heat pump which uses the groundwater as a cold source, gives the possibility of passive cooling.

LITERATURE

1. BURA M., GROZEA A. – 1997 – Îndrumător de lucrări practice la Acvacultură; Litografia USAMVB Timişoara,
2. BURA M. – 2002 – Acvacultură specială; Ed. Orizonturi Universitare Timişoara,
3. CRISTEA V., GRECU IULIA, CEAPĂ C. – 2002 – Ingineria sistemelor recirculante din acvacultură; Ed. Didactică şi Pedagogică R.A. Bucureşti,
4. LOSORDO M.T., MASSER P.M., RAKOCY I. – 1999 – Recirculating aquaculture tank production systems. A review of component opticons; Southern regional aquaculture center, nr. 453.
5. MASSER P.M., RAKOCY J., LOSORDO M.T. – 1999 - Recirculating Aquaculture tank production systems. Management of recirculating systems; Southern regional aquaculture center, nr. 452.
6. PATRICHE N. – 2001 – Păstruga: biologie şi reproducere artificială; Ed. Ceres Bucureşti, 147 pag.
7. RAKOCY J., LOSORDO M.T., MASSER P.M. – 1992 – Recirculating aquaculture tank production systems. Integrating fish and plant culture; Southern regional aquaculture center, nr. 454.
8. INMA Bucureşti – Fundamentarea ştiinţifică a procesului de încălzire/răcire a apei cu pompe de căldură, în sistemele de creştere superintensivă a peştilor