

## SEAWATER INTAKE STRUCTURES

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### Abstract

The seawater intake structures are used, above all, in desalination plants, fish farms and refrigeration circuits for industries and combined cycle gas turbine (CCGT) power stations.

The function of these structures is to collect water of specific characteristics for the required function, and the design thereof must be carried out so that the negative impacts on the environment may be minimised to the utmost and with adequate characteristics relating to temperature, suspended solids, etc.

In this paper we shall focus upon open intake structures on the sea bed. These structures are elements which are, generally speaking, constructed from reinforced concrete or plastic elements (GRP) covered with concrete, the function of which is the collection of the seawater, which is then transported by means of underwater pipelines to the pump stations, which are located on land.

After the types of intake structures have been defined, the principal design parameters shall be set out, and finally, we will describe the most recent experiences in which INCREA has participated as designer and PPA as manufacturer and installer.

### Keywords

Intake structure, collection, desalination plant, intake, outfall, refrigeration, fish farm, intake tower.

## INTRODUCTION

With the recent increase in the construction of seawater desalination plants and of thermal power stations that require refrigeration circuits, as well as other installations that require seawater intake systems, both the number of designs as well as the size of the collection structures have increased.

In respect of this increase, of significant influence has been the possibility of using pipelines of greater diameter, that allow for the water intake by means of a pipe with greater volume capacity, and which logically, require intake towers of greater magnitude.

The function of these structures is to collect water with a temperature and certain quality characteristics which are suitable for the required function, minimising the environmental impact to the surroundings thereof. Such impacts shall depend upon the type of plant, as the requirements for a combined cycle gas turbine (CCGT) power station, which uses the collected water in order to refrigerate the circuit, shall not be the same as those in respect of a seawater desalination plant, the purpose of which is essentially human consumption.

Accordingly, the most habitual types of intake structures shall be summarised, (focusing upon open intake structures on the sea bed), the parameters for the design thereof and the most recent experiences concerning the design and construction of the intake structures, in respect of which the increase of the sizes thereof is able to be verified, which duly creates the need for more sophisticated structures.

## TYPES OF STRUCTURES

The principal types of seawater intake structures are as follows:

### **Wells**

Water is extracted from the phreatic water-table level, at the coast.

The well intakes have the advantage that the water is of higher quality, and accordingly it is a good option for desalination plants. Through the wells, a pump sucks the water, which is then subjected to different filtering systems so as to separate the sand and other impurities.

The disadvantage of this type of seawater intake structure is that the hydraulic capacity will often be reduced by reason of the silting thereof (clogging with fine particles) that impedes the intake of the necessary flow volume.

### **Direct costal intake**

This is normally carried out by means of collection caissons. This type of seawater intake structure is only feasible in certain enclaves, given that the coastal dynamics may “bury them”, and thereby plugging them up. Furthermore, the water collected may be of worse quality, given that along the coast both organic as well as inorganic waste material exists that are dragged along by the marine dynamics. Thus, these intake structures are not recommended in the case of desalination plants or fish farms, but are recommendable for refrigeration circuits. The costal dynamics are also problematic, which may cause changes to the level and profile of the coast, which may generate problems in respect of the functional capacity of the water intake structure.

### **Open intake structures on the sea bed**

These structures usually have a singular collection structure that is located in a convenient position, at a sufficient sea depth, where the water enters into the underwater pipelines, which duly transport the same to land, whereby a pump station pumps the water to its destination. The structure situated in the sea is usually made of concrete or formed by special pieces of GRP (or other plastic materials). The structure is seldom metallic (for the problems of corrosion). This solution is usually the most advantageous, given that the water quality is guaranteed by selecting the most adequate intake point and the hydraulic capacity is unlimited, provided that the intake structure, the pipelines and the pumps (located at the pump station, on land) are of a sufficient size and power.

In this paper we shall focus upon this type of structure, given that it is the most used.



**Figure 1: Most habitual types of direct intake structures on the sea bed**

## **DESIGN PARAMETERS**

The seawater intake structures have a great advantage for refrigeration systems, which is the continuous and inexhaustible provision of large volumes of water. However, due to the fact that the ocean is a dynamic element and that it is always in a continuous state of change both in respect of the surface level as well as of the seabed, the force of the waves and the changing currents may damage the structures and affect the deep sea waters, thereby affecting the quality thereof. Furthermore, an operational problem is added and that is that the marine water is highly corrosive and the marine organisms may intensify this corrosive action, in addition to covering the entire system equipment and even managing to block it completely.

On the other hand, from an environmental point of view, the water intake structures may produce negative impacts to the marine habitat; with the extraction of large volumes of water in the surrounding areas, the biomass available to the primary level of the food chain is thereby reduced, which is comprised of phytoplankton, and this causes a drop in the global productivity of the ecosystem; and furthermore, if the design of the structure is not optimised, it may eventuate that physical injuries are caused to fish and other marine organisms of larger size and accordingly the mortality rate increases.

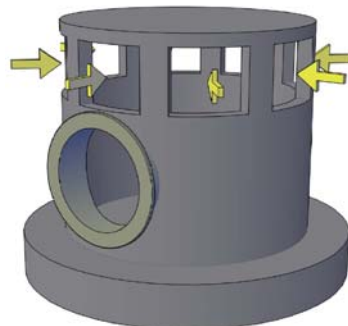
In order to carry out the design of the collection structures it is necessary to take into account numerous aspects that condition the design thereof.

It is important, as with any engineering project, to understand the necessary characteristics for the installation thereof. The water supplied must have certain physical and chemical characteristics that condition the optimal functioning of the system (e.g. turbidity and temperature of the water column), but, furthermore, the circuit must cause the least resistance possible to the flow of water in order to improve its performance; that is to say, it is intended that the roughness of the walls of the pipelines is not increased or of the other elements whereby the water circulates.

The principal design parameters are:

### **Direction of the entry flow**

The conversion from the vertical flow to the horizontal flow reduces by between 80 - 90% the suction of organisms. The quality of the water is greater and we avoid that the deposition of any organic or inorganic waste material may enter into the seawater intake circuit.



**Figure 2: Recommended entry flow**

### **Suction velocity**

This is the velocity of the entry of the seawater into the circuit through the windows. This shall be the function of the flow volume of the water intake and of the section of the collection intake windows. If the suction velocity is low, the impact of the water extraction is minimised, that means that the fish and other organisms enter into the intake pipeline and from there into the installation itself. A range of low velocities also reduces the entry of elements that are suspended in the water, such as sand, sediments, etc. The suction velocity conditions, together with the flow capacity (fixed parameter) the size of the windows, and accordingly, the size of the collection structure. Furthermore, an excessive velocity may mean that a large amount of suspended sand and sand on the seabed is sucked up, causing problems in the pump stations and to the installations, although this factor is also highly conditioned upon the distance from the seabed at which the intake window is located.

Furthermore, logically, at greater velocities, there will be greater losses of hydraulic loading in the entrance.

### Distance of the window from the seabed

Due to the water suction process, the windows must be located at a sufficient distance from the seabed in order to avoid the entrance of suspended sediments. Accordingly, it is recommended to carry out a hydro-dynamic model so as to verify the possible suction of material, carrying out designs with velocities that guarantee that the entry of sediments does not take place. Furthermore, a sufficient distance from the seabed guarantees that there will not be any accumulations of material in the intake tower that could reach the window.

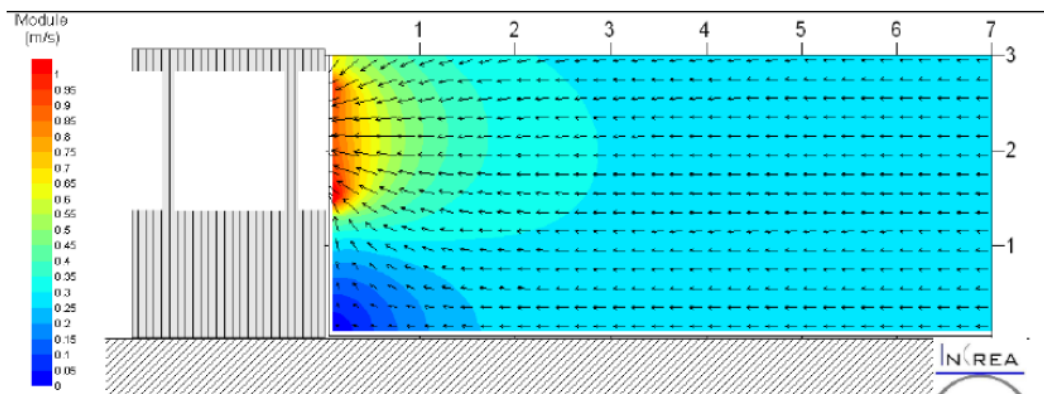


Figure 3: Hydro-dynamic model of the water intake

### Depth of the window

The greatest possible distance is sought between the intake and the water surface for various reasons: to achieve a water intake without floating particles and to avoid the entrance of sestonic species (for example, jellyfish) that are located close to the water surface. Furthermore, with distancing the intake from the surface, the amount of light is reduced, and accordingly certain organisms will be unable to live on the surfaces of the structure. In the case of refrigeration circuits, at a greater depth, lower the water temperature.

The actions of the waves against the tower are, furthermore, reduced when the depth of the intake tower is greater.

The only disadvantage in placing the intake tower at great depths is the cost thereof, given that it implies the installation of a much longer intake pipeline, with the corresponding additional costs of construction and the operation (pumping) thereof.

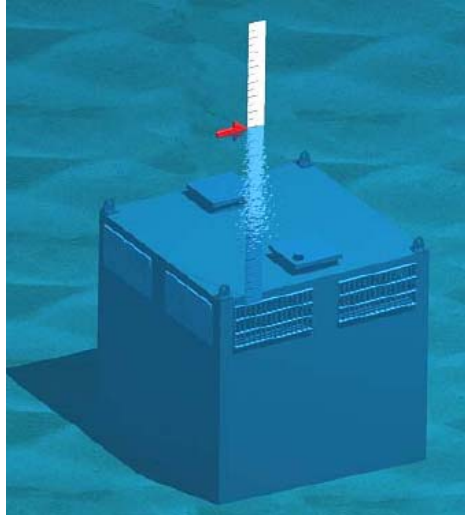


Figure 4: Distance of the intake window from the seabed

### Maritime climate

As with any maritime engineering design project, the wave effect of the enclave of the works is a highly important variable that conditions the dimensions thereof. Logically, significant wave force actions require a stronger structure in order to guarantee the stability thereof. High return periods for the waves are used, given that it is a structure that is exposed to the effects of the sea throughout its useful life. For the calculation of the wave action in the position of the intake tower, it is necessary to carry out a wave propagation study from indefinite depths. The currents, habitually, are of less importance.

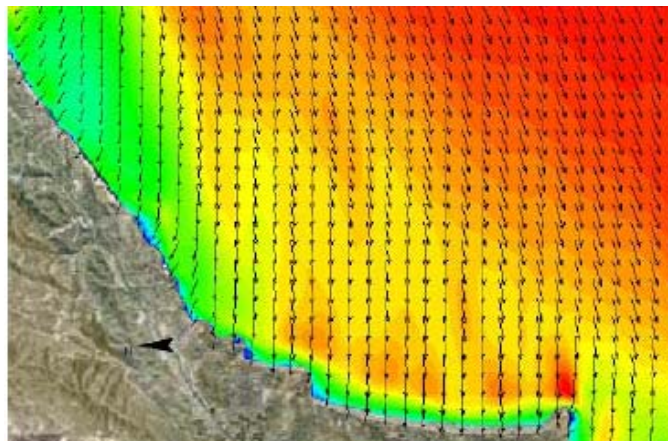


Figure 5: Calculation of the wave action

### Geotechnical stability

A detailed study must be carried out in order to guarantee the geotechnical stability of the structure against upturning, sliding and sinking, conditioning the geometry and the weight of the structure. The force actions upon the tower are originated, principally, by the passing of the wave.

Knowledge of the geotechnical characteristics of the underlying seabed where the tower is to be positioned is of utmost importance.

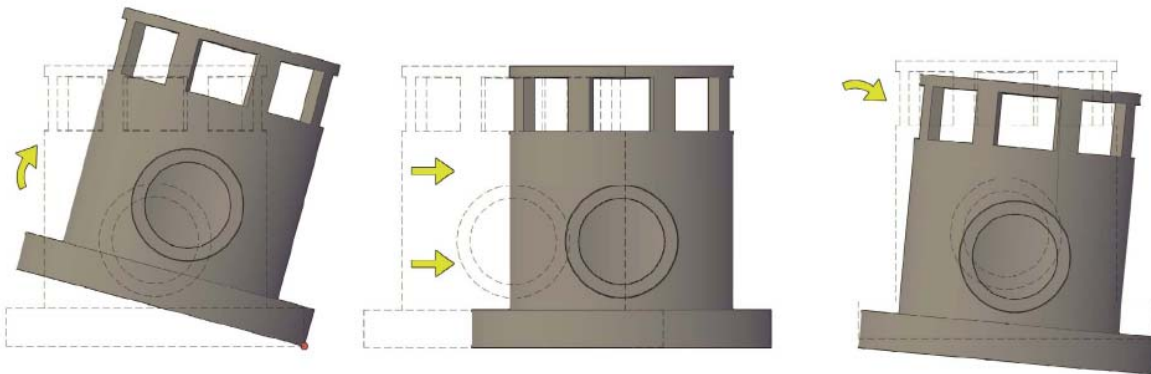


Figure 6: Most common failures of the intake towers: upturning, sliding and sinking

### Structural Dimensioning

The structure must be modelled in order to establish the structural dimensions, so that it is able to support the forces generated by the calculated force actions. In the case of concrete structures, the piece shall be reinforced, and it is recommended to construct a finite elements model, although, often, the minimum amounts place conditions upon the reinforcement thereof. This is because, very often, it is intended that the structure has a significant weight, and accordingly the concrete walls and base plates have significant thicknesses.

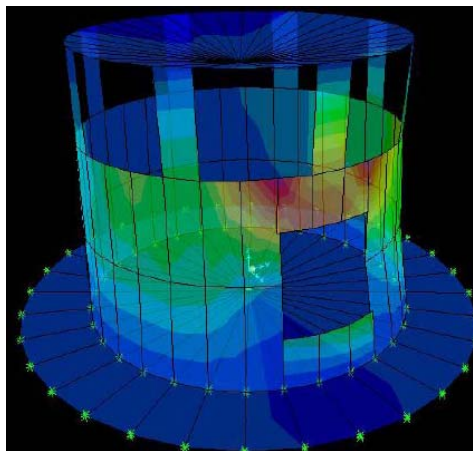


Figure 7: Finite elements model.

### Other conditional parameters

Furthermore, supplementary measures exist in order to improve the design, such as the use of antifouling paints, hypochlorite additions and compressed air or the installation of grates in the windows. If these measures are not carried out fouling deposits may be produced that may even collapse the windows, impeding the entrance of water. Accordingly, the measures in order to guarantee the functioning thereof are of vital importance.

The hypochlorite additions, whether of a continuous basis or in impulses, kills the surrounding living organisms and impedes that the same attach to the walls of the structure, in the same manner as compressed air.



The paints have a reduced useful life of less than one year, and accordingly the principal mission thereof is that of impeding the deposits from the sinking of the intake tower up until the start-up of the installation and accordingly until the initiation of the hypochlorite system and/or additives.



**Figure 8: Deposits in windows of a tower**

### **MOST RECENT EXPERIENCES IN RESPECT OF WATER INTAKES ON THE SEABED**

Over recent years, INCREA has designed a large number of collection structures in highly diverse environments. The majority thereof have already been constructed and are currently functioning to the full satisfaction of the client. We shall detail those that are already concluded (we shall not describe theoretical cases) duly setting out, in this paper, the most significant details thereof and illustrating the same with numerous photographs.

The design parameters are very different, due to, above all, the fact that in many situations the requirements of the client condition the design thereof.

The principal intake structures designed by INCREA over recent years are as follows:

- Square reinforced concrete intake structure for the Seawater Desalination Plant (SDP) of Mutxamel (Alicante, Spain). The tower is buried over a significant length, and accordingly no significant stability problems have existed. The force actions are important due to the shallow depth of the pipe sinking.
- Circular intake structure with external grills for the intake of the SDP of Águilas (Murcia, Spain). The significant flow volumes and entry velocity requirements made this design necessary, which had a significant degree of acceptance in light of a similar design in respect of the desalination plant of Campo de Cartagena.
- (4) Special parts of GRP for the CCPP of Koudiet (Algeria). A design is carried out in GRP in order to avoid the construction of 4 large concrete structures in an enclave where the construction thereof would have been complicated. The structure is protected by way of submerged concrete.
- Square reinforced concrete intake structure for the SDP of Santa Eulalia (Ibiza), where the preliminary design made it necessary to maintain many of the design parameters.

- Octagonal reinforced concrete intake structure for the SDP of Cap D´Jinet (Algeria). The impossibility of using curved formworks by reason of the lack of resources made it necessary to carry out an octagonal tower design.
- Circular reinforced concrete intake structure for the SDP of Mostaganem (Algeria), where the construction complications made it necessary to carry out different tower designs, with the definitive construction of the circular tower.
- Circular reinforced concrete water intake structure for the refrigeration of the fertilizer plant in Arzew (Algeria), where, in addition to constructing a new intake, an Improvement Project of the existing intake structure was carried out.
- Hexagonal reinforced concrete intake structure for the SDP of Skidda (Algeria), where many different designs were also carried out due to the lack of marine resources and the absence of curved formworks.
- Circular reinforced concrete intake structure with external grills for the intake of the SDP of Valdelentisco, Campo de Cartagena (Murcia, Spain).
- Hexagonal reinforced concrete intake structure for the CCPP of Vandellós (Tarragona, Spain).
- Special piece of GRP for the Diesel Plant of Los Guinchos (La Palma, the Canary Islands).

Hereinbelow, we can see schematic diagrams of the dimensions of the most recent towers constructed, in reinforced concrete:

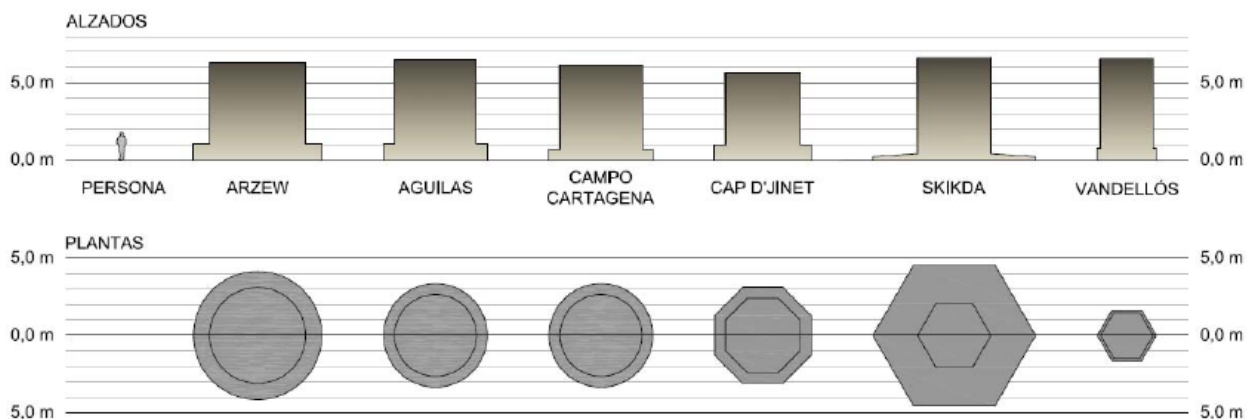


Figure 9: Most recent towers constructed

Many of these towers have been constructed and installed by the Spanish company PPA, which, furthermore, has a great degree of experience in the manufacture and installation of underwater pipelines.

## CONCLUSIONS

The design of a collection structure requires a highly detailed study of the surroundings in which it is to be positioned, as well as a very careful dimensioning thereof.

An incorrect design of this structure may cause the failure of an installation with a cost far in excess of that related to the correct engineering construction tasks.

We recommend an intensive communication with the company which is to carry out the installation, in order to understand the availability of the equipment in the work zone and, accordingly, align the design thereto.